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Effects of Soil Amendment and Fertilizer Applications on Sweet Potato Growth, Production, and Quality

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Introduction

Sweet potatoes are grown in Louisiana on several different types of soil. The soils range from the light-textured, moderately acid Coastal Plains group through the medium-textured, moderately acid Mississippi River terrace and Loessial Hill group to the heavier-textured, slightly acid to neutral soils of the Mississippi and Red River alluvial areas. Some of the soils in the first two groups are strongly acid, having a pH of 5.0 or lower, and a portion of the third group are alkaline, with a pH of 7.0 to 7.5 *(7)*[2]. The natural reaction of some of these soils has been altered in certain fields to some extent by the continued use of fertilizers and/or lime to make them more suitable for the production of crops. As a result of these practices, the pH of any one of the soils mentioned above may vary over quite a wide range.

A high percentage of the commercial sweet potato crop in Louisiana is produced on silt loam soil of the Mississippi River terrace or Loessial Hill group. Generally, the reaction of these soils is acid, varying in pH from 4.8 to 5.8 under natural conditions. However, many of these soils have received lime applications to make them more suitable for production of soybeans, as well as other leguminous crops and certain non-legumes, so that the present pH of some of these soils is above 6.0. Still, they are used to some extent by sweet potato growers, even though they are aware of the potential damage to their crop by the soil rot organism *Streptomyces ipomoea*, as pointed out by Person and Martin *(35)*. On the other hand,

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[2]Italic numbers in parentheses refer to Literature Cited, page 52.

these soils are purposely avoided by some growers of sweet potatoes who are not willing to risk their crop on a terrace or Loessial Hill soil that has been limed. Rather, these growers prefer to use unlimed soil with a pH not much above 5.0 because of their knowledge of or experience with the soil rot problem. Accordingly, through the continuous use of complete fertilizer and long-term cropping to sweet potatoes, some of these soils have become highly acid, with a pH below 4.9 *(7)*. This is an undesirable reaction of the soil from many standpoints of plant nutrition, and certain other crops, such as cotton, tomatoes, and soybeans, are known to suffer from manganese phytotoxicity under highly acid conditions on a Mississippi terrace soil *(33, 38, 44)*. It is well-known that this group of soils is relatively high in total manganese content (*44*). Under moderately acid conditions only a small percentage of the total manganese present is soluble; however, as the soil becomes more acid the solubility of the manganese-bearing salts increases so that additional amounts of manganese may be taken up and accumulated by plants to a point at which toxicity occurs. Therefore, since different plant species have different tolerance levels to manganese in the foliage (*12, 16, 25*), and since no information was available on the question of manganese toxicity in sweet potatoes, and since some sweet potato growers are using highly acid terrace soils for their crop while others are using terrace or Loessial Hill soil that has been limed, it appeared desirable to study the influence of soil reaction in a typical Mississippi terrace soil on the growth and production by sweet potatoes. Quality studies were incorporated into this project in 1967 to determine the effects of soil pH and fertilization on the quality of fresh and processed sweet potatoes.

Review of Literature

The use of sulfur as a soil amendment for controlling sweet potato soil rot, caused by *Streptomyces ipomoea,* has been reported by several investigators (*17, 19, 34, 35, 36*). Sulfur applied in the proper amounts lowers the soil pH to a point at which the soil rot organism will not grow (*34, 35*). However, with the lowering of the soil pH many changes take place in the nutrients in the soil, among which is a marked increase in the solubility of soil manganese, iron, and aluminum (*40, 45*). The increased solubility of these elements can cause a sharp increase in their absorption and accumulation rates by crop plants resulting in phytotoxicity (*5, 16, 22, 27, 30, 33, 40, 41*). This is particularly true for the element manganese. Neal and Lovett found manganese toxicity in cotton growing on Mississippi River terrace soils in Louisiana in which the reaction had decreased to values below 5.0 (*33*). They called the condition "crinkle-leaf" and stated that it occurred fairly commonly in cotton grown on acid terrace or Loessial Hill soils (*33*). A similar situation has been noted with tomatoes and soybeans grown on highly acid terrace or Loessial Hill soil, in which case the manganese toxicity is shown as a characteristic chlorotic pattern in the leaves (*38, 44*).

Evidently, different plant species have wide differences in their tolerance to manganese accumulation in the tissue before showing symptoms of phytotoxicity (*1, 5, 6, 13, 14, 16, 25, 29, 30, 31, 32, 33, 36, 37, 38, 39, 46*). Little information is available on the level of manganese necessary to cause toxicity in sweet potato foliage, although it has been established that a certain level of the element in the foliage is necessary for normal growth and production (*9, 31*).

The use of lime as a soil amendment for sweet potatoes is not a common practice, even though the crop is often grown on low-calcium, moderately acid soil. Several investigators have found the calcium requirement of sweet potatoes to be relatively low (*4, 8, 9, 10, 15, 42*). In experiments by Cibes (*9*), Edmond (*10*), and Spence (*42*) under controlled conditions in which the supply of nutrients was precisely regulated, sweet potato plants grown under a very low calcium regime made good growth and yields comparable to those of the control. In field experiments on a Providence silt loam soil low in native calcium supply (240 ppm), Balerdi (*4*) obtained no response in growth, yield, or calcium uptake to applications of calcium carbonate, sulfate, or chloride. However, in a greenhouse study with a Stough very fine sandy loam containing only 32 ppm of calcium as native supply, he noted marked responses in plant growth and color to calcium applied in the acetate form (*4*). In a field test, Steinbauer and Beattie (*43*) studied the effects of hydrated lime and calcium chloride applied annually to a soil with an original pH of 4.6 to 5.0. After 5 years of work, they concluded that sweet potatoes are tolerant of a wide range in soil pH but grow best and produce highest yields on slightly to moderately acid soil, with yield reductions on alkaline soil. In other studies with sweet potatoes in the field by Jones (*23*), very good plant growth and high yields have been produced on the lighter-textured soils of the Mississippi River and Red River alluvial areas with a high native calcium supply (2,000 to 3,000 ppm) and a high pH (7.0 to 7.5). Conversely, additional experiments located on moderately acid Mississippi River terrace or Loessial Hill soils (pH of 5.0 to 6.0) with a low native calcium supply (400 to 800 ppm), or on Coastal Plain soils of similar reaction and calcium supply, have resulted in very high yields of good quality sweet potatoes in most cases (*23*).

Materials and Methods

This study was begun in 1960. It was located at Chase in Northeast Louisiana on Grenada silt loam (formerly identified as Olivier silt loam), a prominent soil in the Loessial Hills and Mississippi Terrace soil area in Louisiana. Somewhat similar soils in the same area include the Calloway, Loring, and Olivier silt loams. The soil had previously been used for general farming purposes for many years prior to its use for experimentation. A representative sample of the soil used in this work showed that it was acid in reaction with a pH of 5.2.

An experimental area 72 feet wide and 205 feet long was used for this study. This area consisted of six blocks 30 feet long with 5-foot alleys between blocks. Each block was divided into six treatment plots, each plot being 12 feet wide and 30 feet long. Before any treatments were applied, a representative sample was taken of the topsoil and subsoil from each treatment plot. Subsequently, soil amendment and fertilizer treatments were applied to the plots, which were arranged in a Latin square design. By way of preparation, the soil was disked down completely flat. The appropriate amount of lime or sulphur was applied evenly over the surface of each plot, and the material was thoroughly disked into the soil. These amendments were applied in March of each season through the 1971 season, and the soil was allowed to remain flat for about 2 months following application of the amendments. In May the soil was bedded up into rows 4 feet wide and fertilizer was applied to those plots designated to receive it. The fertilizer used consisted of 30 pounds of nitrogen, 60 pounds of phosphate, and 30 pounds of potash during the 1960-70 seasons and 30-60-60 in 1971-73. Each plot consisted of three rows 30 feet long. Planting of the plots was done in May, using slips of Goldrush during the first year and Centennial each year thereafter except in 1971, when the seedling L4-89 was grown, and in 1972, when seedling L4-186 was used. Plants were spaced approximately 12 inches apart by use of a mechanical two-row transplanter. The herbicide Enide was applied to the tops of the rows at the rate of 6 pounds (active ingredient) per acre immediately after planting, and during the early part of the growing season the water furrows were cultivated as necessary to control weeds. A stand count was taken at about 2 weeks after planting. Irrigation water was applied as necessary to get good growth and production. During the growing season in some years, representative samples of the foliage and soil were taken periodically from the center row of each plot for analysis in the laboratory. The results of these analyses appear in some of the following tables.

The plots were harvested in September or October each year. At harvest, only the roots from the center row were used for records, and the roots were graded into classes of Number 1, Number 2, or Cull, according to U.S. Department of Agriculture standards. The weight of each grade was determined and recorded by plot. The roots from each plot were transported to Baton Rouge for evaluation as to incidence and severity of disease infection. Once this was accomplished, the roots were analyzed and processed. The analyses consisted of dry matter and carotenoid pigment determinations, and the processing procedure involved canning and later evaluating the quality of the pack.

At harvest 10 roots from each plot were cut longitudinally, one-half being used for flesh color analyses and the other half for dry matter determinations. Duplicate 10- to 12-gm. samples of grated tissue to be used for dry matter determinations were dried for 24 hours at 80°C. in a forced-air oven. After drying, the samples were ground to pass through a 40-mesh screen in a Wiley mill and were subjected to fiber and protein analyses according to Association of Official Agricultural Chemists procedures (*3*).

Optical densities (flesh color) of 0.1 gm.-samples of tissue homogenized with 10 ml. of hexane were determined at 440 mu with a Beckman DB-G recording spectrophotometer. Carotenoid content was determined by comparison with a Beta-carotene standard curve. Duplicate color samples were tested from each plot. Flesh color of canned sweet potatoes was determined as for fresh potatoes, with the exception that benzene was used as the solvent.

Canning grade roots were processed 1 to 2 days after harvest. Standard canning procedures were followed and consisted of lye peeling in 10 percent sodium hydroxide at 218° F., washing, trimming, filling the cans with hot 30 percent cane sugar syrup, exhausting until the center can temperature reached 180° F. (about 3½ minutes), sealing, and retorting for 35 minutes at 240° F. After water cooling, the canned potatoes were stored at room temperature for at least 3 months before evaluation.

Firmness of canned sweet potatoes was determined by use of a Food Technology Corporation shear press with recorder, utilizing a 250-pound proving ring, 200 gms. of sweet potatoes in a 10-prong standard shear cell, and a 30-second stroke at 100 pounds of pressure.

Data were also obtained on "cracking" or "splitting" of the roots in the cans. Total root count was taken along with total "splits" and "severe splits" (roots that would be expected to fall apart upon shipping).

In taking samples of the foliage during the growing season, the leaves were sampled in each plot by position from the terminal bud. Each visible leaf was counted, whether opened or not, starting at the terminal of the vine. Leaves number 6, 10, and 14 were the ones most frequently sampled, but in some cases leaves were taken from other positions on the vine. Within a 30-plant plot, every other hill was sampled, with only one representative vine from the hill being used in the sample. Once a leaf was taken from a certain position on the vine it was combined with the 14 other leaves from that same position taken within a plot. Thus, each foliar sample consisted of 15 leaves taken from the same position on different vines in the same plot. Each leaf collected was rated for the presence and severity of chlorotic symptoms by comparison with a previously-prepared standard. The leaves were then thoroughly washed in tap water and distilled water and dried in a forced-air oven at 65° C. for 24 hours. After drying, the leaves were ground fine enough to pass through a 20-mesh screen in a stainless steel Wiley mill and used for chemical analyses.

At harvest time, six Number 1 and six Number 2 roots within a plot were composited for dry matter determinations and certain other chemical analyses. A 10-gram sample of the freshly ground tissue was taken for the dry matter measurement. The remainder of the ground roots were dried in a forced-air oven at 65°C. and ground fine enough to pass through a 20-mesh screen in a Wiley mill. This tissue was used for chemical analyses.

In analyzing either leaf or root tissue, a 1-gram sample was weighed into a Gooch crucible and ashed in a Blue M Electric Co. Model M25A muffle furnace for 4 hours at 550° C. Then 10 ml. of a 50 percent HCl solution was used to dissolve the ash. This solution was heated until it cleared up and then filtered throughWhatman No. 2 filter paper. The filter paper was washed with hot water several times, and the volume was made up to 100 ml. with distilled water, giving a 1:100 sample dilution. From this solution, the manganese and magnesium contents were determined on a Perkin-Elmer Model 303 atomic absorption spectrophotometer. The calcium content was determined on a Beckman Model D. U. flame spectrophotometer in 1969 and on the atomic absorption spectrophotometer in 1970. Aluminum was determined colorimetrically by a modified aluminon method (*46*). Iron was determined by the orthophenanthroline method (*2*), and phosphorus was determined by the vanadate method (*2*).

In the soil analysis work, the pH was determined by using a 1:1 soil/water mixture and allowing it to stand overnight (*7*). The pH value was determined with a Corning Model 10 pH meter.

A 5-gram sample of soil was extracted with 50 ml. of a 1 N ammonium acetate solution buffered at a pH of 4.8 to determine manganese, iron, aluminum, calcium, and magnesium contents (*11, 18, 20, 28, 48, 49*). The method used, described by Jackson (*21*), involved weighing out 5 grams of soil into a centrifuge tube and then adding 25 ml. of the extracting solution. The centrifuge tube was stoppered and shaken on a mechanical shaker for 30 minutes. The samples were then centrifuged at approximately 3,000 rpm for 5 minutes. The supernatant liquid was poured onto Whatman No. 2 filter paper and collected in a 50 ml. volumetric flask. Then 25 ml. of the extracting solution was added to the centrifuge tube. It was then stoppered and shaken for 10 minutes, centrifuged for 5 minutes, and filtered. The volumetric flask was filled to volume with extracting solution. The manganese and magnesium contents of the sample were determined on a Perkin-Elmer Model 303 atomic absorption spectrophotometer. The calcium content was determined on a Beckman Model D. U. flame spectrophotometer in 1969 and on the atomic absorption spectrophotometer in 1970. Aluminum was determined colorimetrically, using a modified aluminon method described by Vogel (*46*). Iron was determined colorimetrically, using the dipyridyl method described by Kumada (*24*).

All other soil samples were analyzed by the Louisiana State University Soil Testing Laboratory, using well-known methods of analysis (*7*).

Beginning in 1965, data were obtained on soil rot severity in each of the experimental plots. During the growing seasons of 1965, 1966, and 1970, ratings were made of vine growth on plants in the center row of each plot 7 to 9 weeks after planting according to the following scale: 1 = poor vine growth with most of the plants severely stunted; 2 = fair vine growth but clear evidence of some effects of disease or chemical injury; 3 = good vine growth with little or no evidence of disease; 4 = very good, vigorous vine growth. These data were analyzed statistically, considering amendments and fertilizer as fixed effects and years as random effects. At harvest, each sweet potato was placed into one of the following five soil rot severity classes: 0 = none, 1 = trace, 2 = slight, 3 = moderate, and 4 = severe. From these data the percentage of sweet potatoes affected by soil rot was determined, and a soil rot severity index was calculated for each plot by the following formula:

$$\frac{\text{Sum of (No. of potatoes in each class x class No.)}}{\text{(No. of potatoes classed) x (No. of classes — 1)}} \text{ x } 100 = \text{severity index}$$

Thus, if all sweet potatoes were free of soil rot and were placed in 0 class the severity index would be 0, and if all sweet potatoes had only a trace of soil rot and were placed in class 1 the severity index would be 25, and so on, until finally if all sweet potatoes were severely affected with soil rot and were placed in class 4 the severity index would be 100.

The combined data for the 7 years 1965-1970 and 1973, when the Centennial cultivar was planted, were analyzed statistically for both the percentage of sweet potatoes affected by soil rot and soil rot severity indexes. In the analyses, amendments and fertilizer were considered as fixed effects and years as random effects. The data for 1971 and 1972 were omitted from the combined analyses because a moderately resistant (L4-89) and a resistant (L4-186) cultivar were planted, respectively, during the 2 years.

Results and Discussion

Each of the soil amendments applied had a rather pronounced effect upon the soil reaction, as shown in Figure 1. The application of sulfur had a depressing effect on the soil pH, beginning with the first year of application and continuing throughout the experimental period. This effect tended to disappear during the last two seasons when no soil amendments were applied to any of the plots. The pH of the sulfur-treated soil, initially at 5.2, dropped to levels well below 5.0 and in some cases reached a low point of 4.4 as the seasons passed. Except for 1964 and 1965, the use of fertilizer with the sulfur application had little bearing on the acidifying effect of the amendment.

Conversely, the addition of lime to the soil reduced the soil acidity (increased the pH) from the first year on throughout the experimental period (Figure 1). In fact, this amendment had changed the reaction of the soil from an initial pH value of 5.2 up to the point of neutrality (7.0) by the end of the sixth season. Beyond that season, the pH remained at or near neutrality for the remainder of the experimental period. Again, as was the case with sulfur applications, the effect of lime on soil pH tended to fall off during the last year when no additional lime was used on the soil. With this amendment, the use of fertilizer showed a tendency to lower the soil pH fairly consistently. (In formulating the fertilizer used, ammonium nitrate, ordinary superphosphate, and muriate of potash were used as nutrient carriers.)

The reaction of the soil which did not receive any amendment showed little change during the first few years, but during the later years of the experiment a gradual rise in the pH was indicated (Figure 1). This change in the pH was not expected and cannot be explained on the basis of border effect, since all plots were well-guarded and every precaution was taken during all field operations not to mix the soil from one plot with that of another one. Furthermore, all soil and plant samples were taken only from the center row of each 3-row plot. In this case again, the application of fertilizer resulted in a lower soil pH than that of unfertilized soil.

The influence of soil amendment and fertilizer applications on the level of extractable phosphorus from the soil is shown in Figure 2. During the first few years of the study, there was no clear-cut relationship between experimental treatment and phosphorus level, but as the seasons passed a definite trend gradually emerged indicating that all of the plots receiving fertilizer applications contained more extractable phosphorus than those not receiving fertilizer. During the later years, among the fertilized plots there were no consistent differences in phosphorus content due to the type of soil amendment used. Among the unfertilized plots, which were much lower in extractable phosphorus, only questionable differences occurred as a result of soil amendment use. Thus, it was apparent that fertilizer

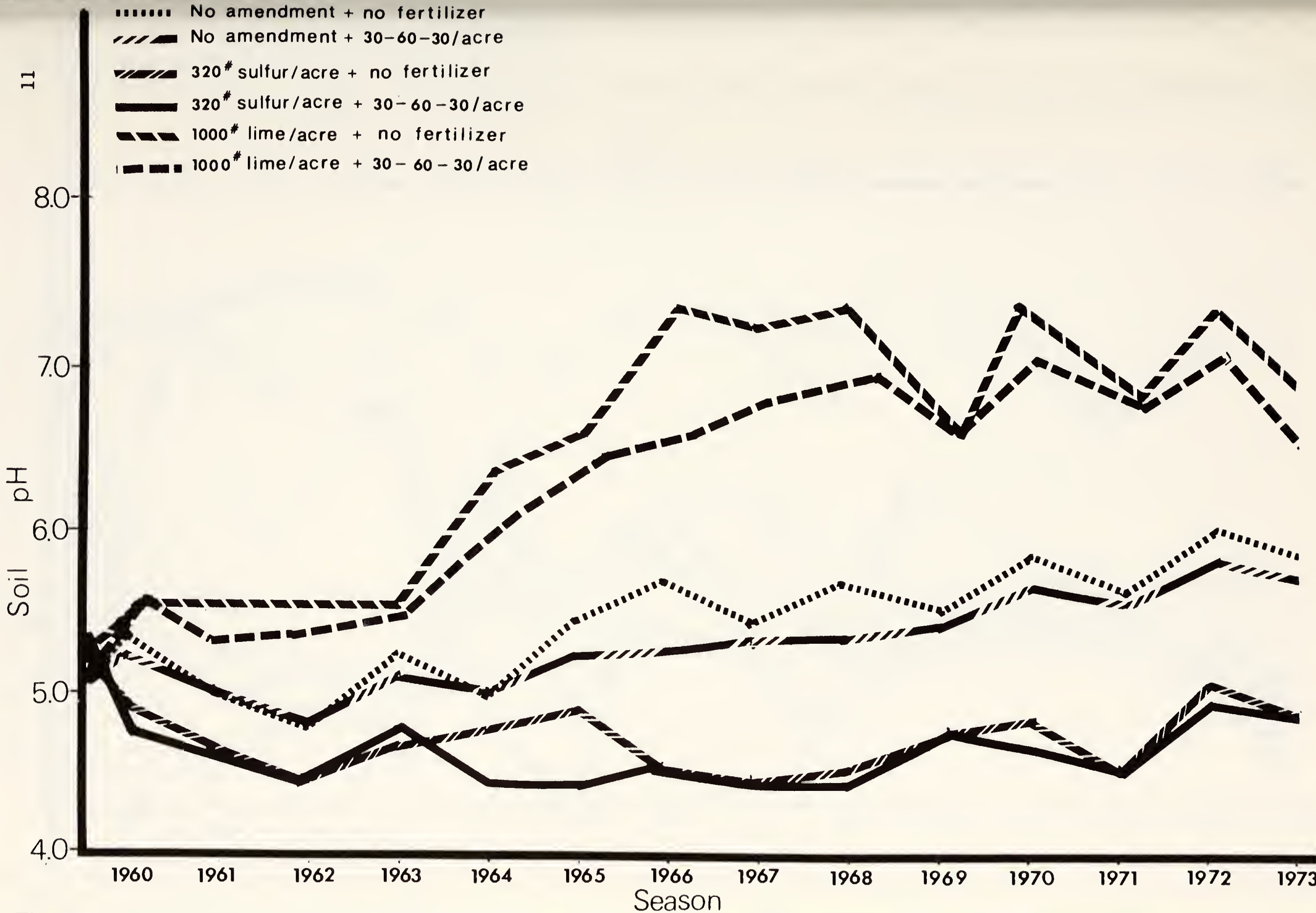


Figure 1. — The reaction of Grenada silt loam soil used for sweet potato production as affected by soil amendment and fertilizer applications, Chase, La., 1960-73.

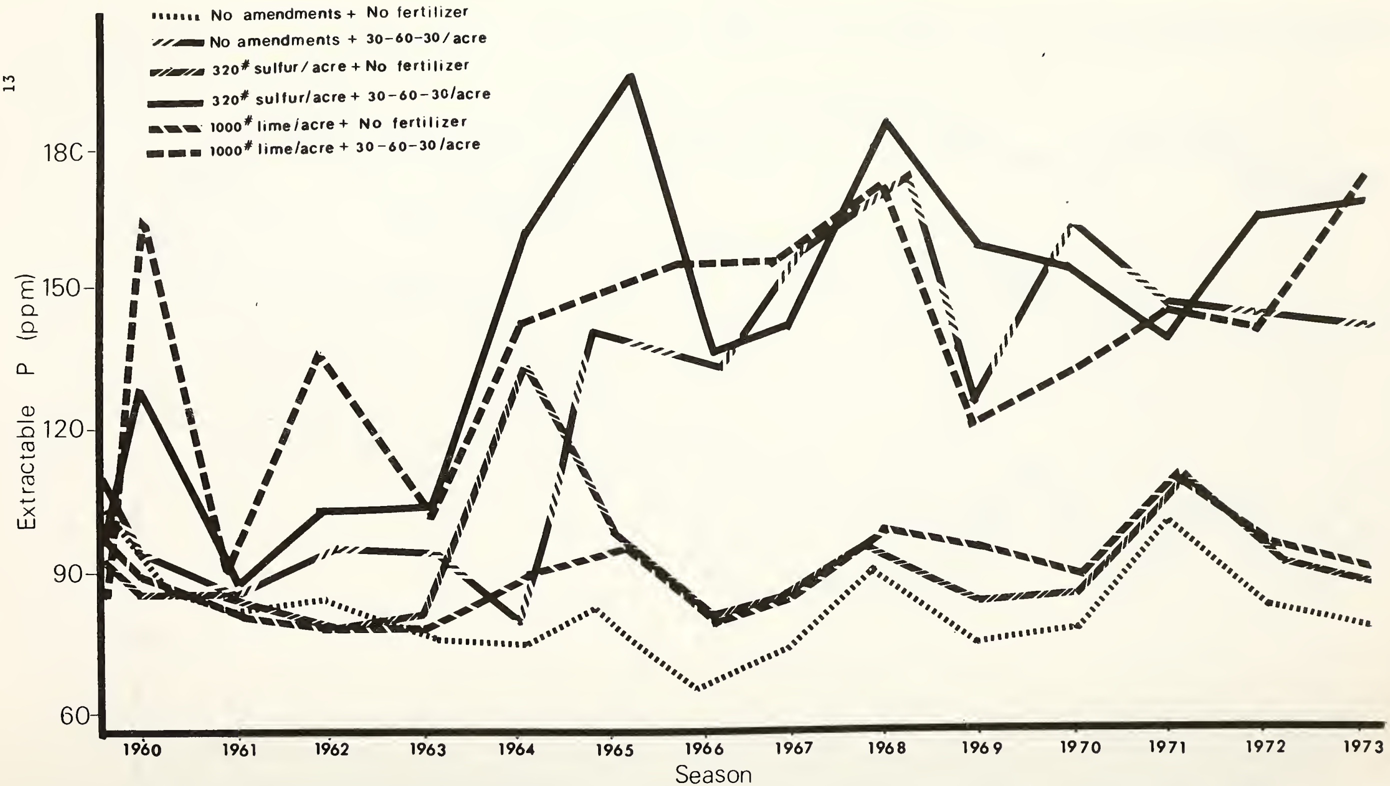


Figure 2. — Extractable phosphorus content of Grenada silt loam soil used for sweet potato production as affected by soil amendment and fertilizer applications, Chase, La., 1960-73.

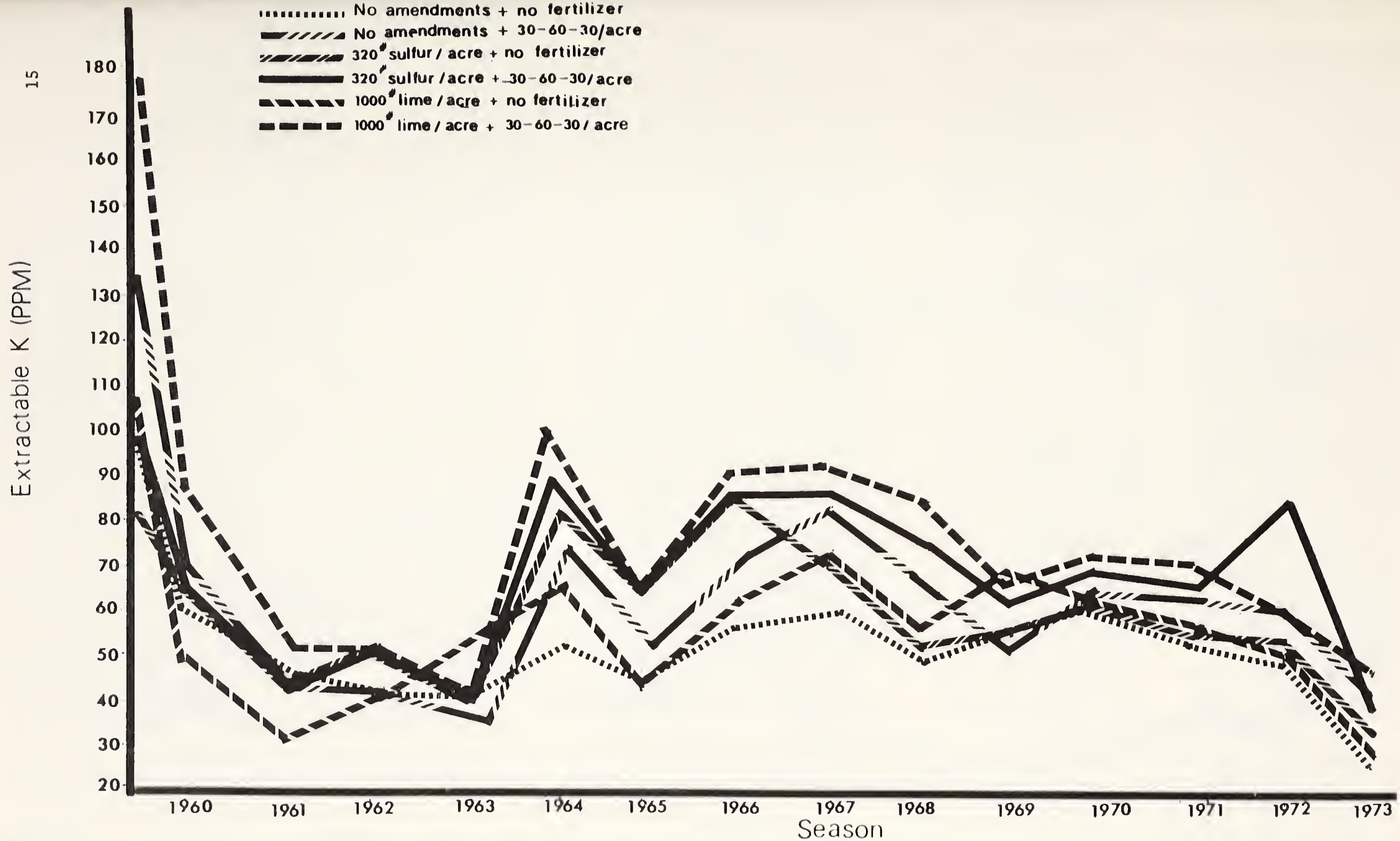


Figure 3. — Extractable potassium content of Grenada silt loam soil used for sweet potato production as affected by soil amendment and fertilizer applications, Chase, La., 1960-73.

applications were responsible for much larger differences in extractable phosphorus from the soil than was the use of these two soil amendments, even with their pronounced effects upon the soil reaction shown in Figure 1. At the end of the experimental period, all of the plots having received fertilizer applications were considerably higher in extractable phosphorus content than they were at the outset of the experiment. On the other hand, the unfertilized plots were somewhat lower in phosphorus than they were in the beginning.

The extractable potassium in the soil was not strongly affected by soil amendment or fertilizer applications, as shown in Figure 3. A rather pronounced decrease was indicated in all plots during the growing season of 1960. After that, the potassium level remained fairly even throughout the experimental period, with no definite accumulation being indicated in the fertilized plots. In the last year, 1973, the soil was much lower in extractable potassium in all plots than it was at the beginning of the experiment.

The extractable calcium level in the soil was markedly affected by soil amendment applications (Figure 4). The effect of lime applications was first shown during the initial few years of the study, and the peak in calcium accumulation was reached at the 1966 season. Following that, no further buildup of extractable calcium was indicated in the lime-treated soil. The use of sulfur apparently depressed the concentration of extractable calcium in the soil, this response being manifested after the first few applications of sulfur and lasting throughout the remainder of the study, with one inconsistency indicated in the 1964 season. Little difference in soil calcium could be attributed to the use of fertilizer, regardless of the amendment applied.

Differences in extractable magnesium followed a pattern similar to that of calcium (Figure 5). Lime applications increased the magnesium levels while sulfur applications decreased them throughout the period. Again, the use of fertilizer had little effect on extractable magnesium levels.

The interrelationships of soil reaction to various other soil factors over the entire 14-year period are presented in Table 1 in the form of correlation coefficients. The level of extractable phosphorus did not show a close dependence on the soil pH, and potassium extractability was not related to soil reaction in any way. On the other hand, both calcium and magnesium were extractable in proportion to rises in the soil pH value. Further, these two elements were positively related to each other in their extractability from the soil. Conversely, extractable calcium had little influence on the amount of potassium extracted from the soil, nor did magnesium have any effect on this process.

The data in Table 2 show that the plant stand of sweet potatoes was not materially affected by either the soil amendments or fertilizer applied over the 14-year experimental period. Only in the 1965 season was there any

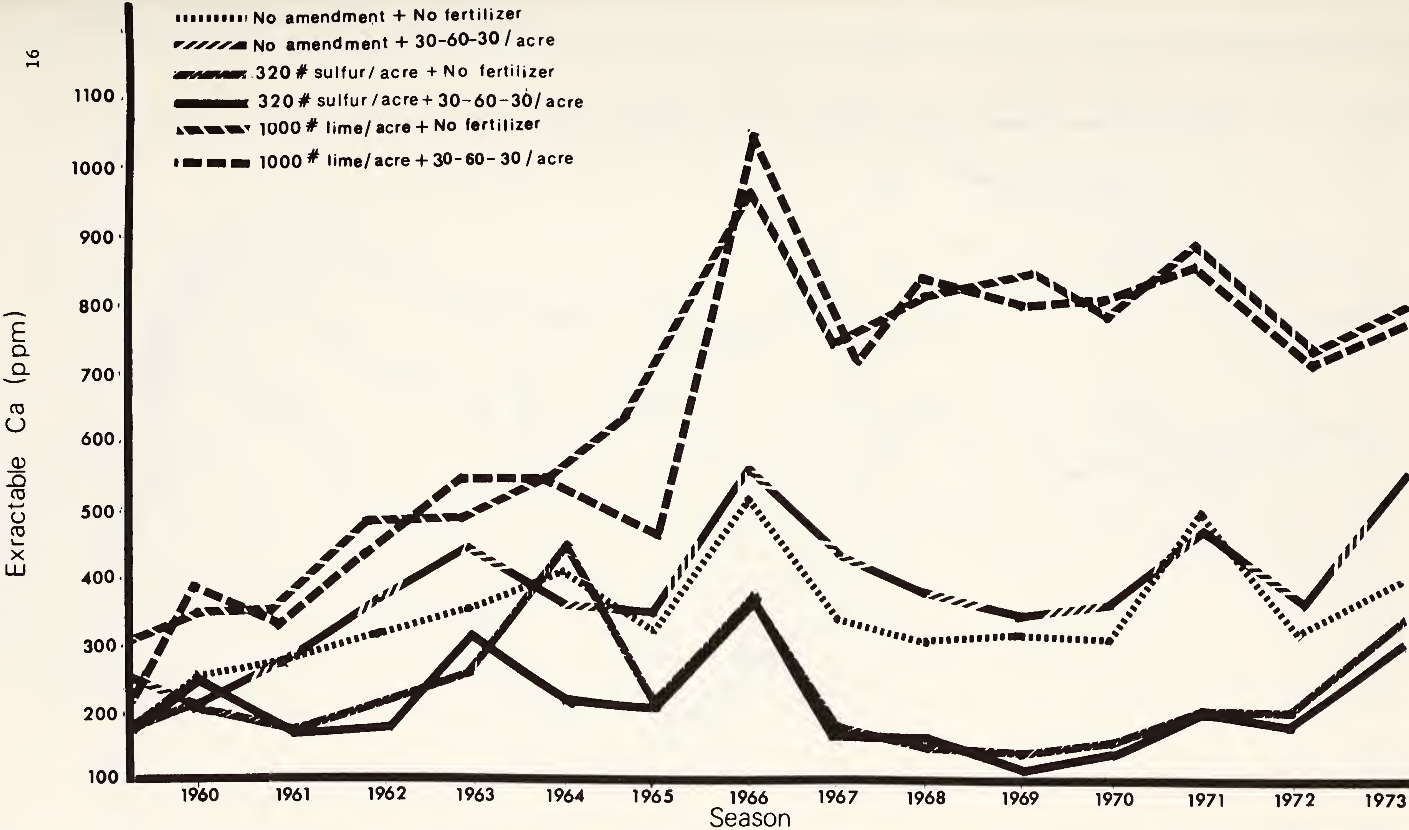


Figure 4. — Extractable calcium content of Grenada silt loam soil used for sweet potato production as affected by soil amendment and fertilizer applications, Chase, La., 1960-73.

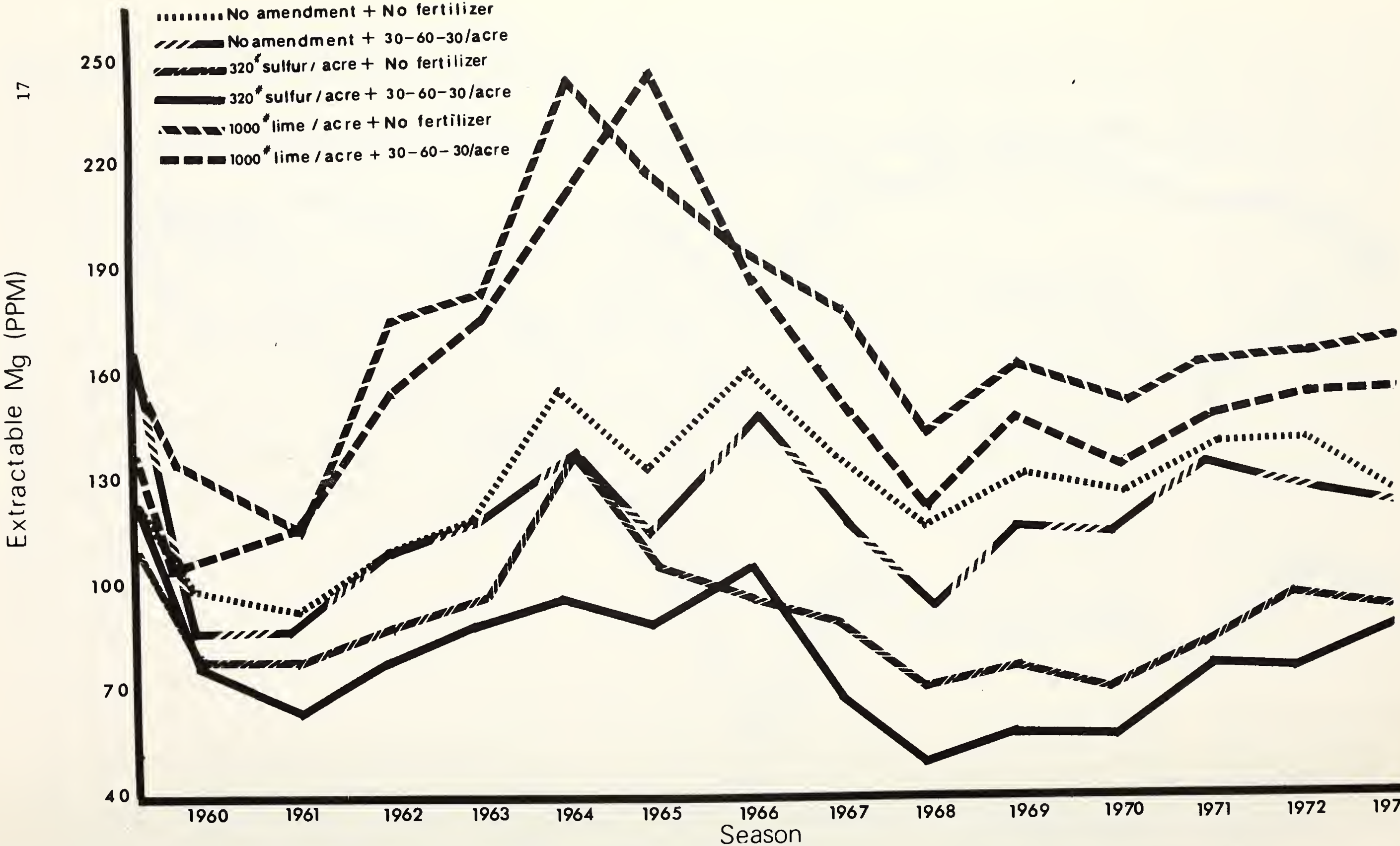


Figure 5. — Extractable magnesium content of Grenada silt loam soil used for sweet potato production as affected by soil amendment and fertilizer applications, Chase, La., 1960-73.

Table 1. — The relationship between the soil reaction and the levels of extractable* phosphorus, potassium, calcium, and magnesium during the 14-year period, 1960-73

Soil Variables	r Value
Soil pH with Extractable Soil Phosphorus	0.44**
Soil pH with Extractable Soil Potassium	-0.002
Soil pH with Extractable Soil Calcium	0.87**
Soil pH with Extractable Soil Magnesium	0.71**
Extractable Soil Calcium with Extractable Soil Magnesium	0.83**
Extractable Soil Calcium with Extractable Soil Potassium	-0.04
Extractable Soil Magnesium with Extractable Soil Potassium	0.04

*Extracted with 0.1 N HCl at a soil:extractant ratio of 1:20 except for phosphorus in which case 0.03 N NH_4F was included in the extractant.

**Significant at the .01 level of probability.

real indication of a difference in plant stand due to treatment. This indication appears of minor consequence in view of the remainder of the data indicating no relationship between experimental treatment and plant stand. The stand during the first year was poor in all plots. This result was ascribed to dry soil and warm weather at planting time, along with the recognized tendency of the Goldrush cultivar to give poor stands when planted under adverse conditions. The following year and for the next 9 years the Centennial cultivar was substituted for Goldrush, and a good plant stand was obtained in all plots. In the 1971 season, the seedling L4-89, which is resistant to the soil rot organism, was planted instead of Centennial to study the possible response by this variety to a "high-calcium, high-pH" soil. A good stand was obtained with no association between treatment and stand present. Another seedling, L4-186 which is highly-resistant to soil rot, was planted in all plots in the 1972 season. Again, a very good stand resulted in all plots. Then in the 1973 season, the Centennial variety was used again and, as in previous years, showed an almost perfect stand in all plots.

The effects of the soil amendments and fertilizer on the production of Number 1 grade sweet potatoes are presented in Table 3. During the first year with the Goldrush cultivar, none of the combinations of amendment and fertilizer was beneficial in terms of yield. The most noticeable result was the depression in yield by sulfur applications. In the following year when Centennial was planted, the yields were increased by the use of fertilizer, with an additive effect being indicated between lime and fertilizer. These results, although not significant, were shown again in the 1962 season except for the low yield where sulfur and fertilizer were both applied. In 1963 the pattern changed somewhat in that production from the limed soil showed a downward trend. This was brought about by the beginning of infection of some of these potatoes with soil rot which relegated these particular roots into the Cull class. By the 1963 season the

Table 2. — The stand of sweet potatoes[1] grown on Grenada silt loam soil as affected by soil amendment[2] and fertilizer applications, Chase, La., 1960-73

	No. of Plants/Acre														
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Avg.
No Amendment- No Fertilizer	6,534	9,801	9,620	8,469	8,894	11,315	11,253	11,315	11,616	11,435	10,465	9,195	10,770	10,647	10,095
No Amendment 30-60-30/A[3]	6,353	9,500	9,739	8,469	8,774	11,373	11,072	11,554	11,736	11,435	10,709	9,318	10,709	10,890	10,117
320# S/A - No Fertilizer	5,688	9,620	10,044	8,832	8,531	11,191	11,435	11,798	11,496	11,315	10,647	9,400	11,072	11,315	10,170
320 # S/A - 30-60-30/A[3]	5,870	9,739	10,102	8,531	8,774	11,373	11,315	11,678	11,072	11,253	10,770	9,137	11,373	11,072	10,147
1,000# Lime/A[4] No fertilizer	6,534	9,801	9,921	8,531	8,774	11,315	11,373	11,554	11,616	11,496	10,589	8,955	11,010	10,952	10,173
1,000# Lime/A[4] 30-60-30/A[3]	5,870	9,681	10,044	8,531	8,955	11,796	11,191	11,554	11,736	11,435	10,465	9,137	10,952	10,952	10,164
LSD (.05)	NS	NS	NS	NS	NS	465	NS	NS	NS	NS	NS	NS	NS	NS	NS
LSD (.01)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1] Goldrush in 1960, Centennial in 1961-70, L4-89 in 1971, L4-186 in 1972, and Centennial in 1973; planted in May each year and harvested in September.

[2] Applied broadcast in March the first 11 years, then none thereafter.

[3] The 30-60-30/A rate applied in the row in early May each year for the first 11 years, then 30-60-60/A annually thereafter.

[4] Dolomite applied the first 5 years, then calcite the next 6 years, then none.

Table 3. — Yield of Number 1 sweet potatoes[1] grown on Grenada silt loam soil as affected by soil amendment[2] and fertilizer applications, Chase, La., 1960-73

Treatment	Number One Roots (Bu./Acre)														
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Avg.
No Amendment-No Fertilizer	329	298	336	166	107	140	201	111	91	80	146	82	39	73	159
No Amendment - 30-60-30/A[3]	302	336	387	248	145	142	380	177	143	152	235	171	73	114	215
320# S/A - No Fertilizer	209	292	328	138	127	132	301	142	284	144	132	65	51	107	168
320# S/A - 30-60-30/A[3]	242	350	292	232	104	157	336	220	221	138	161	136	60	198	203
1000# Lime/A[4] - No Fertilizer	334	329	349	167	74	52	70	30	17	17	90	114	68	31	124
1000# Lime/A[4] - 30-60-30/A[3]	301	408	396	201	88	94	151	73	31	56	122	150	90	84	160
LSD (.05)	83	65	NS	52	NS	NS	79	49	37	51	55	42	26	52	47
LSD (.01)	114	NS	NS	71	NS	NS	107	67	51	69	75	57	NS	70	65

[1] Goldrush in 1960, Centennial in 1961-70, L4-89 in 1971, L4-186 in 1972, and Centennial in 1973 - planted in May each year and harvested in September.

[2] Applied broadcast in March the first 11 years, then none thereafter.

[3] The 30-60-30/A rate applied in the row in early May each year for the first 11 years, then 30-60-60/A annually thereafter.

[4] Dolomite applied the first 5 years, then calcite the next 6 years, then none.

pH of the soil in the limed plots had reached a point around 5.5 (Figure 1). Additional presentation of results and discussion of the extent of soil rot infection undergone by the roots from each of the plots in the experiment are given later in this bulletin. In the 1963 season, the beneficial effects of fertilizer were shown with each amendment treatment. The fertilized plots not receiving any amendment showed some indication of superiority. (Reference to Figure 1 will also show that the sulfur-treated plots had become highly acid by the 1963 season.) During the next two seasons, the yields were low from all plots with the greatest depression in the limed plots due primarily to a high percentage of the roots being infected with soil rot. In 1966, the yields were back up to more normal levels. The use of fertilizer was beneficial to each amendment treatment; however, the amendments even applied with fertilizer reduced the yield below that of the control. The inferiority of the limed soil was clearly shown.

For the remainder of the experimental period, 1966-73, the data indicated, with some exceptions, that the use of sulfur as an amendment was of no benefit to yield, especially when used in conjunction with fertilizer. Further, the use of lime was definitely detrimental to production of Number 1 potatoes, whether it was used with fertilizer or not, because of continued infection of the roots by the soil rot organism. The highest yields and the best plant growth were obtained from fertilized soil which had not received any amendment application.

In the 1971 season when the seedling L4-89 was grown, the detrimental effects of the lime amendment were greatly reduced, since the soil rot organism does not affect this seedling to any great extent. However, there was no indication of a benefit from lime applications as was noted during the first few years of the experimental period, presumably before the soil rot organism had time enough to build up a sufficient population to cause significant damage to the crop. Conversely, the use of sulfur caused a greater reduction in yield than the use of lime in this season.

During 1972, the yields by plants of the L4-186 seedling were so low that it was considered inappropriate to draw any inferences from the data obtained.

In 1973 when Centennial was planted again, the detrimental effects of lime were clearly demonstrated once more. It may be recalled that no amendments had been applied to the soil since 1970, but Figure 1 shows that the limed soil still had a pH value of about 6.5, one that favors the growth and activity of the soil rot organism.

The yield of Number 2 potatoes as affected by soil amendment and fertilizer is presented in Table 4. As was the case with Number 1 roots, these yields varied considerably from season to season. Although the differences in yield were significant within certain seasons, they were not significant in others, and no over-all patterns of treatment effects were established. A definite sign of yield depression was shown in the center

Table 4. — Yield of Number 2 sweet potatoes[1] grown on Grenada silt loam soil as affected by soil amendment[2] and fertilizer applications, Chase, La., 1960-73

Treatment	Number Two Roots (Bu./Acre)														
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Avg.
No Amendment-No Fertilizer	42	120	98	183	168	40	74	23	27	71	60	29	31	34	71
No Amendment - 30-60-30/A[3]	31	113	55	188	190	41	70	22	35	129	59	39	31	36	74
320# S/A - No Fertilizer	36	127	79	186	150	27	42	41	38	88	39	38	33	62	70
320# S/A - 30-60-30/A[3]	28	97	69	139	160	25	60	24	51	85	39	35	31	65	65
1000# Lime/A[4]-No Fertilizer	42	114	99	126	110	11	13	1	4	16	31	44	36	15	47
1000# Lime/A[4] - 30-60-30/A[3]	28	109	78	157	180	13	85	11	8	96	51	40	34	25	65
LSD (.05)	16	NS	26	NS	50	20	33	15	23	44	NS	NS	NS	25	16
LSD (.01)	22	NS	NS	NS	NS	NS	45	21	31	61	NS	NS	NS	34	22

[1]Goldrush in 1960, Centennial in 1961-70, L4-89 in 1971, L4-186 in 1972, Centennial in 1973 - planted in May each year and harvested in September.

[2]Applied broadcast in March the first 11 years, then none thereafter.

[3]The 30-60-30/A rate applied in the row in early May each year for the first 11 years, then 30-60-60/A annually thereafter.

[4]Dolomite applied the first 5 years, then calcite the next 6 years, then none.

portion of the experimental period in the limed plots, especially those without fertilizer. This was related to the development of soil rot lesions in the roots from these plots. During the 1971 and 1972 seasons when the soil rot resistant seedlings were grown, there was no indication of a yield depression caused by the application of lime.

The production of Cull grade potatoes was markedly affected by soil amendment and fertilizer applications (Table 5). During the first several years, differences in yield were either small or not consistently associated with treatment, but by the 1963 season when production of Number 1 roots began to decline in the limed soil (Table 3), the yield of Cull roots began to increase in the same plots (Table 5). Beginning in 1964, the limed plots receiving fertilizer consistently produced more Cull grade roots than any other plot, as long as Centennial was used as the test cultivar. Ranking second were the plots receiving fertilizer but no amendment. The sulfur-treated soil produced relatively few Culls, whether the soil was fertilized or not. The soil receiving no fertilizer or amendment and that receiving lime but no fertilizer produced intermediate yields of Cull roots. The two soil rot resistant seedlings, L4-89 and L4-186, showed little response to amendment treatment but did indicate some response to fertilizer application (Table 5).

The total yield of sweet potatoes was affected to some extent by soil amendment and fertilizer applications (Table 6), but moreso in some seasons than in others. In the first year with Goldrush, a depressive influence was shown by sulfur application, with or without fertilizer. The use of lime tended to increase the yield, especially when applied with fertilizer. In the next season when Centennial was used, the depressing effect of sulfur was not found, but a tendency was still shown by lime applications to increase the yield. This was also true for fertilizer used with each amendment. During the following year (1962), the results from the limed plots were the most outstanding while production from the sulfur-treated was lowest. Then in 1963, the picture began to change as production from the limed plots started to decrease and that from the plots receiving no amendment began to increase with respect to each other. Data in Table 3 indicate that the yield of Number 1 potatoes showed a similar pattern and was related to a gradual increase in the development of soil rot in the roots produced by the limed plots (Table 5). By the following year, 1964, the limed soil was definitely depressing the yield, as was the sulfur amendment. This trend continued over the next 6 years, with the plots receiving fertilizer but no amendment being clearly superior to the others. During this period, the beneficial effects of fertilizer were shown with all amendment treatments. The lowest yield was obtained from the limed plots receiving no fertilizer. During the seasons of 1971 and 1972 the yields by the soil rot resistant seedlings were not depressed by the limed soil, nor were they increased by it. With the L4-89 a yield depression was indicated

Table 5. — Yield of Cull sweet potatoes[1] grown on Grenada silt loam soil as affected by soil amendment[2] and fertilizer applications, Chase, La., 1960-73

Treatment	Cull Roots (Bu./Acre)														
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Avg.
No Amendment-No Fertilizer	83	70	59	80	36	91	73	192	111	74	51	90	157	82	89
No Amendment - 30-60-30/A[3]	109	60	85	44	35	122	40	325	211	108	142	108	178	168	124
320# S/A - No Fertilizer	79	77	50	68	13	71	38	122	62	60	50	79	160	59	71
320# S/A - 30-60-30/A[3]	75	69	74	30	18	63	36	152	57	91	48	85	223	87	79
1000# Lime/A[4]-No Fertilizer	99	64	55	127	74	108	45	311	169	46	67	86	177	50	105
1000# Lime/A[4] - 30-60-30/A[3]	158	53	68	64	70	170	99	380	276	158	212	123	168	140	153
LSD (.05)	36	NS	NS	55	34	45	40	69	32	19	49	NS	NS	40	35
LSD (.01)	49	NS	NS	NS	46	61	NS	94	44	26	67	NS	NS	55	49

[1]Goldrush in 1960, Centennial in 1961-70, L4-89 in 1971, L4-86 in 1972, Centennial in 1973 - planted in May each year and harvested in September.

[2]Applied broadcast in March the first 11 years, then none thereafter.

[3]The 30-60-30/A rate applied in the row in early May each year for the first 11 years, then 30-60-60/A annually thereafter.

[4]Dolomite applied the first 5 years, then calcite the next 6 years, then none.

Table 6. —Total yield of sweet potatoes[1] grown on Grenada silt loam soil as affected by soil amendment[2] and fertilizer applications, Chase, La., 1960-73

Treatment	Total Yield (Bu./Acre)														
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Avg.
No Amendment-No Fertilizer	457	485	493	428	311	271	347	327	229	225	258	201	221	189	317
No Amendment - 30-60-30/A[3]	445	509	527	479	370	305	490	524	388	390	436	317	282	318	413
320# S/A - No Fertilizer	324	495	456	392	290	230	381	293	281	293	220	182	243	228	308
320# S/A - 30-60-30/A[3]	344	515	435	403	282	244	433	397	325	313	248	255	315	351	347
1000# Lime/A[4] - No Fertilizer	474	505	502	420	258	171	128	342	190	79	188	243	281	96	277
1000# Lime/A[4] - 30-60-30/A[3]	487	570	542	422	339	275	335	463	316	310	385	313	292	249	378
LSD (.05)	71	NS	54	NS	53	NS	74	55	41	84	100	52	57	45	49
LSD (.01)	97	NS	74	NS	73	NS	100	75	56	114	136	71	NS	62	69

[1]Goldrush in 1960, Centennial in 1961-70, L4-89 in 1971, L4-186 in 1972, Centennial in 1973-planted in May each year and harvested in September.

[2]Applied broadcast in March the first 11 years, then none thereafter.

[3]The 30-60-30/A rate applied in the row in early May each year for the first 11 years, then 30-60-60/A annually thereafter.

[4]Dolomite applied the first 5 years, then calcite the next 6 years, then none.

Table 7. — Grade of sweet potatoes[1] grown on Grenada silt loam soil as affected by soil amendment[2] and fertilizer applications, Chase, La., 1960-73

Treatment	Grade of Roots (% No. 1)														
	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Avg.
No Amendment - No Fertilizer	72.0	61.2	67.8	39.0	34.8	48.9	56.3	34.2	37.0	31.2	58.5	40.7	16.3	36.0	45.3
No Amendment - 30-60-30/A[3]	68.2	65.5	73.0	51.8	38.5	45.6	78.0	34.2	37.2	39.2	54.5	54.2	25.3	36.0	50.1
320# S/A - No Fertilizer	62.2	58.2	71.3	35.5	43.2	54.4	78.7	50.2	65.8	48.8	60.3	34.2	20.5	45.1	52.0
320# S/A - 30-60-30/A[3]	69.3	67.3	66.7	58.0	37.2	63.7	78.0	55.8	67.8	43.8	64.2	50.3	17.7	56.2	56.9
1000# Lime/A[4] - No Fertilizer	69.7	64.5	69.7	40.0	25.8	23.5	48.2	9.5	9.5	23.3	38.2	46.5	22.7	35.3	37.6
1000# Lime/A[4] - 30-60-30/A[3]	61.8	71.5	73.3	47.3	25.7	31.3	44.5	16.2	10.0	17.3	30.3	48.2	30.0	34.1	38.7
LSD (.05)	13.7	6.5	NS	10.4	NS	21.7	18.9	12.8	10.8	10.9	14.0	10.8	8.6	13.9	8.9
LSD (.01)	18.7	8.9	NS	14.1	NS	29.3	25.6	17.4	14.7	14.9	19.0	NS	NS	NS	12.5

[1]Goldrush in 1960, Centennial in 1961-70, L4-89 in 1971, L4-186 in 1972, Centennial in 1973-Planted in May each year and harvested in September.

[2]Applied broadcast in March the first 11 years, then none thereafter.

[3]The 30-60-30/A rate applied in the row in early May each year for the first 11 years, then 30-60-60/A annually thereafter.

[4]Dolomite applied the first 5 years, then calcite the next 6 years, then none.

for the sulfur amendment, but this did not occur with L4-186. A positive response was shown by both seedlings to fertilizer applications, whether used with a soil amendment or not. In the last year of the study with Centennial again being used as the test cultivar, the detrimental effects of limed soil were clearly demonstrated, as were the beneficial effects of fertilizer used.

The grade of raw roots produced in this experiment was definitely influenced by soil amendment treatment (Table 7). During the first few seasons, the differences in grade attributable to amendments were relatively small although sometimes significant, but as the seasons passed these differences grew wider, so that after ten years the limed plots were producing roots of a much lower grade than the sulfur-treated soil or that which had received no amendment. As pointed out before, this influence on grade was brought about primarily by the greater incidence and severity of soil rot in the potatoes grown on the limed soil. The use of fertilizer appeared to have little bearing on the grade of roots, whether it was applied with an amendment or not. The grade of roots produced by the L4-89 and L4-186 seedlings was not adversely affected by the limed soil, presumably because of their resistance to soil rot.

Beginning with the harvested roots in 1967, a study was conducted of the influence of the soil amendment and fertilizer treatments previously described on certain quality aspects of the potatoes. This study was continued until the end of the experimental period in 1973.

The effects of fertilizer use as an average of soil amendment treatments on the quality of the three cultivars of sweet potatoes grown in this experiment are presented in Table 8. Over a 4-year period, the Centennial control plots without fertilizer were the highest in dry matter content. With the cultivar L4-89, the fertilizer treatment produced potatoes with a higher dry matter content. However, no significant difference was found from fertilization of the L4-186 cultivar. Increasing the soil pH produced a highly significant linear decrease in the dry matter content of Centennial and L4-89 (Figure 6). Soil pH had no influence on the dry matter content of L4-186.

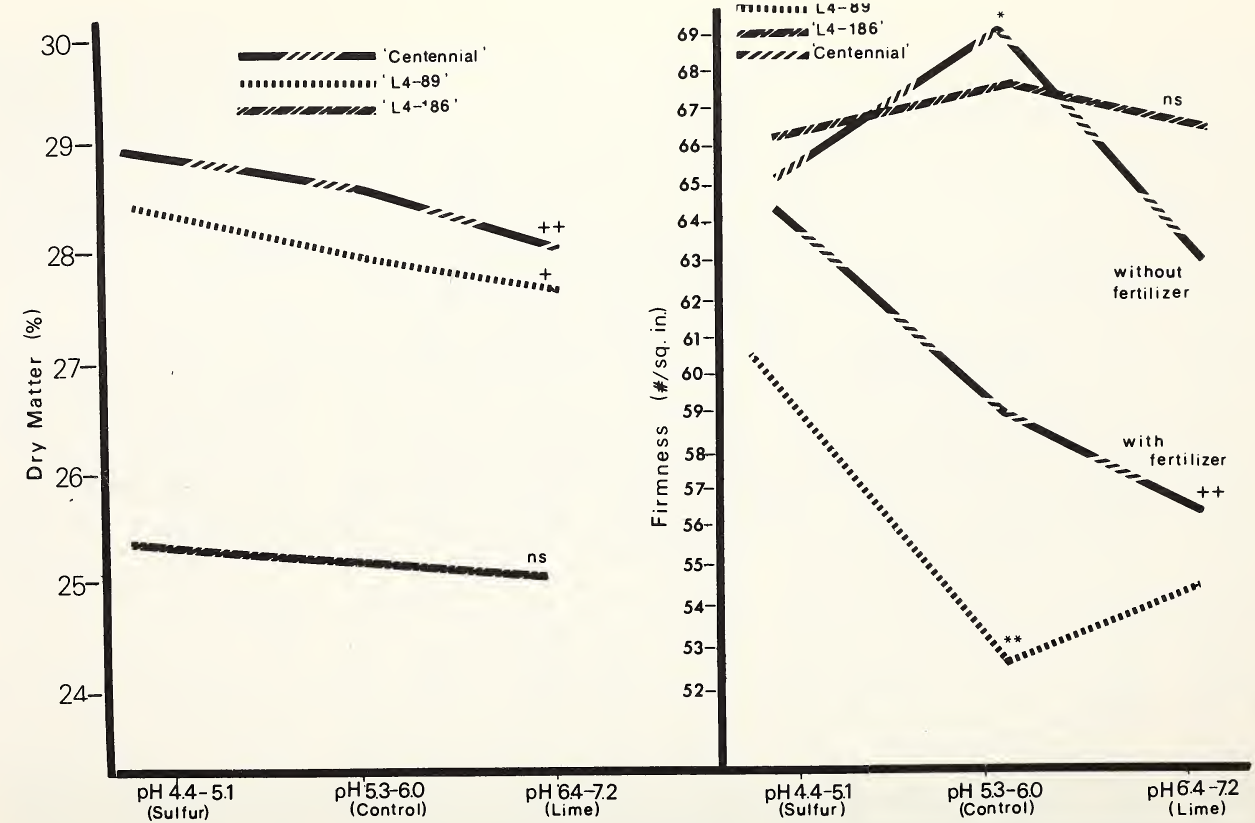
Canned potatoes from plots receiving no fertilizer were significantly firmer in the Centennial cultivar but were softer in L4-186 (Table 8). Firmness of L4-89 was not affected by the addition of fertilizer. A significant interaction occurred between soil pH and fertilizer use with the Centennial cultivar over a 5-year period (Figure 6). Whenever fertilizer was applied, with increasing soil pH there was a highly significant linear decrease in firmness of canned Centennial roots (Figure 6). Without fertilizer, a significant quadratic effect occurred, with the control producing the firmest potatoes. A significant quadratic effect also occurred with L4-89, but the control treatment produced the softest potatoes (1 year's data).

Varying the soil pH by amendment or additions of fertilizer had no

Table 8. — Effects of fertilizer (average of three soil amendment treatments) on quality factors of three cultivars of sweet potatoes

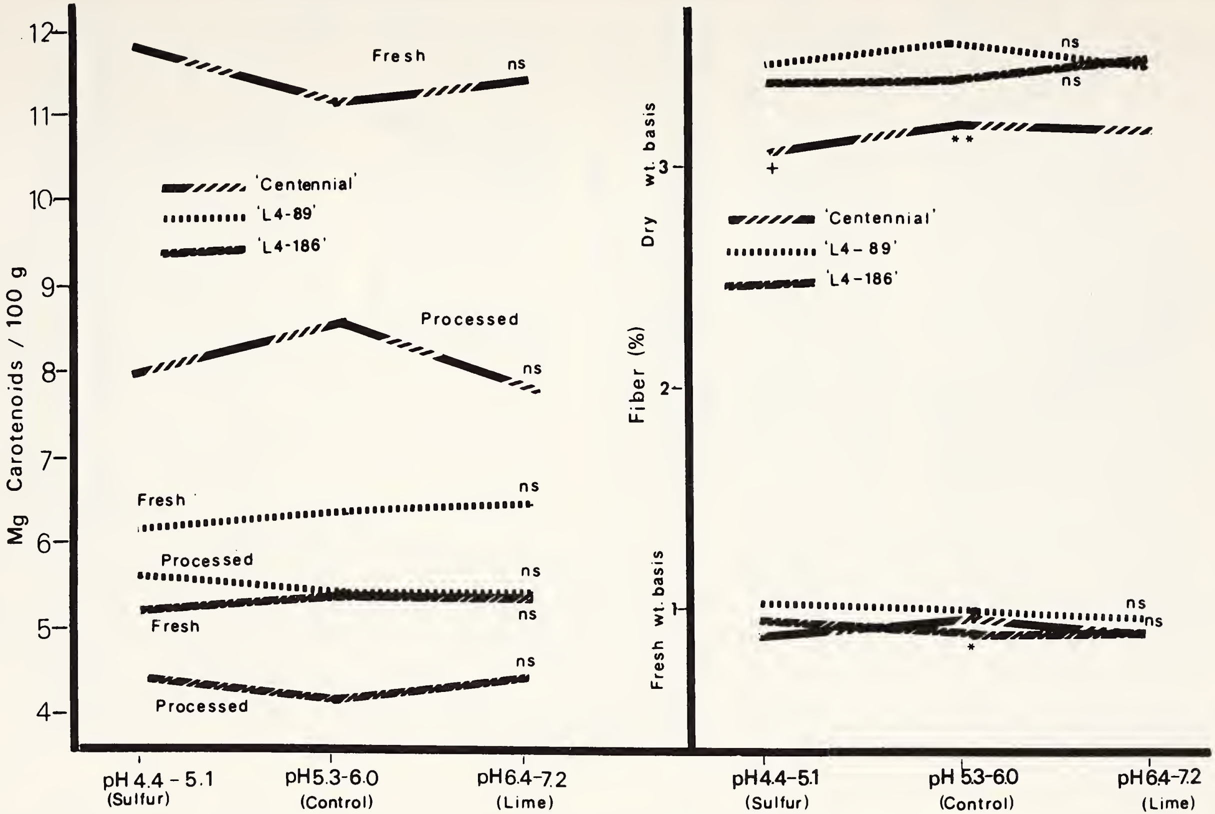
Cultivars	Percent dry matter	Firmness[z]	Color[y] fresh	Color[y] canned	Percent fiber dry wt.	Percent fiber fresh wt.	Percent protein dry wt.	Percent protein fresh wt.	Percent "splits" total	Percent "splits" severe
'Centennial'										
0-0-0	28.8**x	65.9**w	11.4 v	8.1	3.17 v	.88*	5.71 v	1.63	45.6 t	23.2
30-60-30	28.0	59.8	11.4	8.1	3.21	.86	6.59**	1.77**	40.0	18.5
			N.S.	N.S.	N.S.					
'L4-186'										
0-0-0	25.0 t	63.4 t	5.1 t	4.1	3.50**t	.87	4.14 t	1.03	21.4 t	9.1
30-60-30	25.5	70.1**	5.5	4.4	3.33	.85	4.96**	1.28**	16.4	4.5
	N.S.		N.S.	N.S.		N.S.			N.S.	N.S.
'L4-89'										
0-0-0	27.6 t	55.5 t	5.3 t	6.3	3.51 t	.97	4.12 t	1.14	--	--
30-60-30	28.4*	56.3	5.4	6.1	3.46	.98	4.78**	1.36**	--	--
		N.S.	N.S.	N.S.	N.S.	N.S.				

[z] Pounds per sq. inch required to shear a 200 gm sample with shear press.
[y] Mg carotenoid pigments/100 gms.
[x] Average of 4 years' data - 1967, 1968, 1970, 1973.
[w] Average of 5 years' data - 1967-1970, 1973.
[v] Average of 3 years' data - 1969, 1970, 1973.
[u] Average of 2 years' data - 1970, 1973.
[t] Average of 1 year's data.
*Significant at the 5% level.
**Significant at the 1% level.
N.S. - Non-significant.



*,** control significantly different at the 5% and 1% levels, respectively. ns - non-significant.
+,++ limed plots significantly different from the sulfur plots at the 5% and 1% levels, respectively.

Figure 6. — Effects of soil amendments (varying soil pH) on dry matter content and firmness of canned sweet potatoes of three cultivars.



*,** control significantly different at the 5% and 1% levels, respectively.
+ sulfur plots significantly lower in fiber than limed plots. (5%)   ns - non-significant.

Figure 7. — Effects of soil amendments (varying soil pH) on carotenoids and fiber content of three sweet potato cultivars.

measurable influence on the flesh color (carotenoid pigments content) of fresh or processed sweet potatoes of any of the three cultivars used (Table 8; Figure 7).

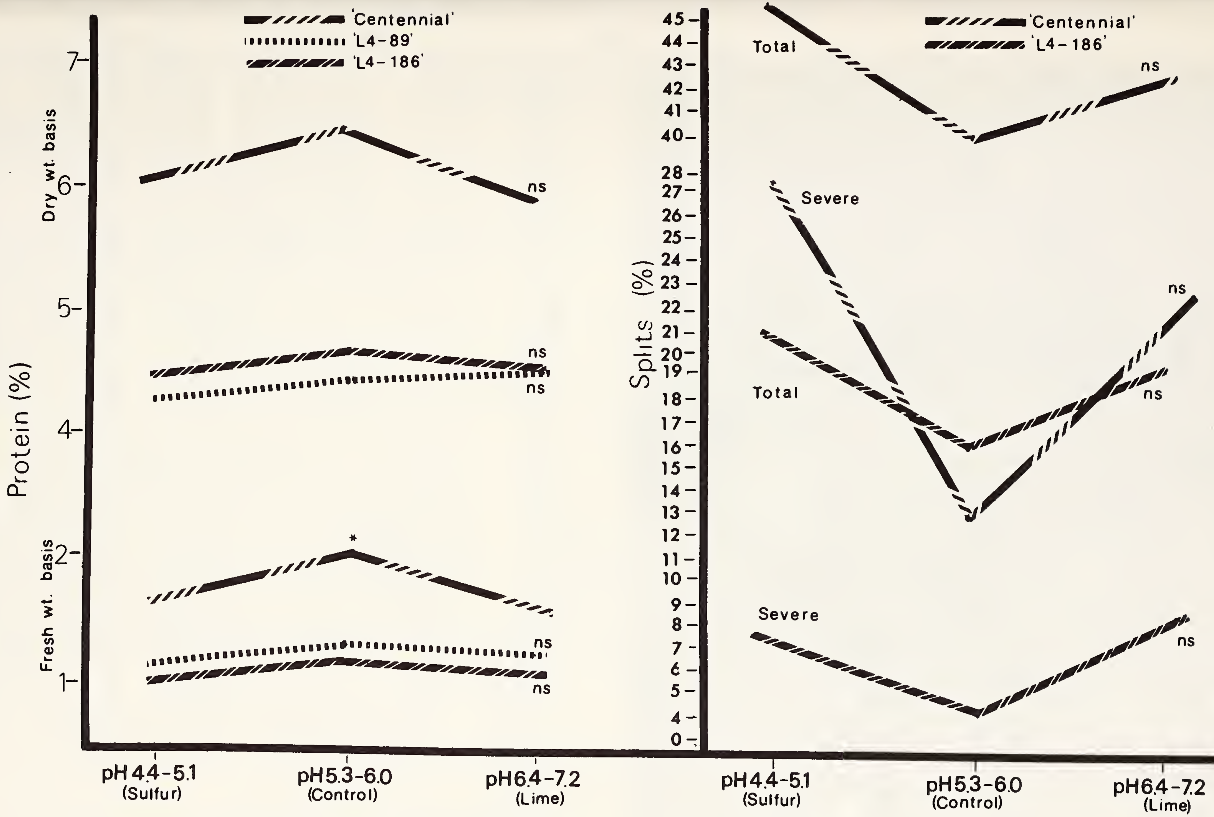
Increasing the soil pH was responsible for a significant linear increase in the fiber content of Centennial sweet potatoes when fiber is expressed as a percentage of the dry matter (Figure 7). This increase in fiber content was rather small. When expressed on a fresh weight basis, a significant quadratic effect occurred, with the control roots (soil pH 5.2) having a higher fiber content. Soil pH had no influence on the fiber content of L4-89 or L4-186 (1 year's results). The addition of fertilizer lowered the fiber content in the Centennial cultivar on a fresh weight basis and in L4-186 on a dry weight basis. However, the use of fertilizer with the cultivar L4-89 had no influence on the fiber content.

Soil pH had some influence on the protein content of one of the three cultivars studied (Figure 8). In the Centennial cultivar, a significant quadratic effect occurred, with the control having the higher protein content (fresh weight basis). The addition of fertilizer did significantly increase the protein content of all three cultivars, both on a fresh and dry weight basis (Table 8).

"Splitting" of the canned roots of Centennial or L4-186 was not influenced by the addition of fertilizer or by variations in soil pH (Table 8; Figure 8). Large variations occurred among replications in "splitting," with the intermediate soil pH level having the lowest percentage of "split" potatoes and "severe splits."

Potatoes from the lime-treated plots had severe soil rot infection, especially on the Centennial cultivar. Soil rot did occur at the intermediate soil pH of 5.3 but not as severely as at pH 6.3. Soil rot lesions greatly reduced the yield of canned potatoes due to the excessive trimming required. Soil rot lesions appeared as black spots on the roots after lye peeling. Sweet potatoes severely infected with soil rot could result in losses during lye peeling and trimming of up to 50 percent.

During the early part of the growing season of 1962, or 3 years after the annual applications of soil amendments and fertilizer had begun, an abnormality appeared on the foliage of the plants growing in the sulfur-treated plots. These symptoms may be described as interveinal chlorosis with some necrosis in severe cases and appeared primarily on the fully mature leaves. Symptoms were less noticeable on the younger expanding leaves and the older leaves near the crown of the plants. A typical plant affected with these symptoms is shown in Figure 9. It may be recalled by reference to Figure 1 that by this time the soil pH in the sulfur-treated plots had dropped to about 4.5. As the growing season of 1962 progressed and the vines extended in length, the severity of the symptoms on the newly-formed leaves was not as striking in appearance as it has been on the younger plants. In fact, by the end of August, practically no symptoms could be found on the foliage that had been formed since the middle part of



* control significantly different at the 5% level. ns - non-significant.

Figure 8. — Effects of soil amendments (varying soil pH) on protein content and splitting of three cultivars of sweet potatoes.

Figure 9. — Effects of the application of sulfur to the soil and the resulting decrease in the soil pH on the presence of chlorotic symptoms on a sweet potato plant growing in the field.

the growing season. Thus, for the rest of the season the foliage of the plants in the sulfur-treated plots appeared perfectly normal and comparable to that which had received no soil amendment treatment (control).

This type of behavior was shown during each subsequent growing season by the plants growing in the sulfur-treated soil. Actually, the symptoms became more pronounced with each passing season; however, they tended to disappear after the early part of the growing season each year. In 1965, it was decided to determine the manganese content of some of the leaves showing marked symptoms of abnormality, since manganese toxicity had been shown to occur in other crops in Louisiana on Mississippi Terrace soils under highly acid conditions. In an effort to avoid any possible influence that fertilizer might have had on the manganese concentration of the foliage, only the unfertilized plots were sampled for analysis, although in the sulfur-treated soil both the fertilized and unfertilized plants were showing pronounced symptoms of a similar degree of severity.

Within a 30-plant plot, one vine from every other hill was selected for the sample. One leaf was taken from this vine at a certain nodal position and combined with another leaf from the same nodal position in the next sampling hill. This procedure was continued until a total of 15 leaves representing a certain nodal position (number from terminal bud) was collected and included in a single sample from each plot. This method of sampling was followed to obtain samples from every other node on the vines growing in the control plot, the sulfur-treated plot, and the limed plot. In using this technique of sampling, it was possible to determine the effect of relative age of leaf as well as soil amendment on the concentration of manganese in the foliage. Along with the foliar samples, a representative sample of the topsoil was taken for pH and extractable manganese determinations. These samples were taken on August 4, 1965, and the results of the analyses of the soil and the leaves are presented in Table 9.

The annual application of amendments had exerted a marked effect on the soil reaction by the 1965 season (Table 9). The use of sulfur had lowered the soil pH to 4.5 while lime applications had raised the value to 6.3. Sulfur applications also greatly increased the extractability of manganese from the soil. On the other hand, lime use only slightly reduced the extractable soil manganese.

The foliar samples from the untreated plots increased in manganese

Table 9. — Soil reaction, extractable soil manganese*, and manganese content of sweet potato leaves** taken from different positions on the vines which had received different soil amendment treatments, 1965

Amendment	Soil pH	Extractable Soil Mn-PPM***	Leaf Position from Terminal Bud	Manganese Content-PPM****
None	5.5	27	Terminal- 2	137
None	5.5	27	- 4	188
None	5.5	27	- 6	275
None	5.5	27	- 8	320
None	5.5	27	-10	362
None	5.5	27	-12	400
None	5.5	27	-14	328
320# Sulfur/A	4.5	165	Terminal- 2	1,325
320# Sulfur/A	4.5	165	- 4	1,825
320# Sulfur/A	4.5	165	- 6	3,000
320# Sulfur/A	4.5	165	- 8	3,025
320# Sulfur/A	4.5	165	-10	2,750
320# Sulfur/A	4.5	165	-10	3,275
320# Sulfur/A	4.5	165	-12	800
1000# Lime/A	6.3	20	Terminal- 2	190
1000# Lime/A	6.3	20	- 4	225
1000# Lime/A	6.3	20	- 6	370
1000# Lime/A	6.3	20	- 8	320
1000# Lime/A	6.3	20	-10	388
1000# Lime/A	6.3	20	-12	425
1000# Lime/A	6.3	20	-14	438
1000# Lime/A	6.3	20	-16	462
1000# Lime/A	6.3	20	-18	250

* Extracted with 1 N ammonium acetate buffered at pH 4.8.
**Sampled on August 4, 1965 along with the soil.
***PPM of the air-dry soil.
****PPM of the oven-dry tissue.

concentration with age of leaf up to the tenth to twelfth node, after which a slight decline in manganese was indicated. These leaves, which appeared completely normal and healthy before analysis, contained from 137 ppm in the youngest leaves to 400 ppm in those 12 nodes from the terminal bud.

The leaves from the sulfur-treated soil were much higher in manganese concentration. Again, the younger leaves were considerably lower than the older ones, with a maximum, 3275 ppm, being reached at the tenth leaf from the terminal bud. Before analysis, these leaves were showing pronounced symptoms of abnormality while the younger leaves with lesser concentrations of manganese, 1395 ppm, were showing milder symptoms. The oldest leaves (node 12) were lowest in manganese concentration (800 ppm). The vines in this plot appeared to be shorter with a smaller number of internodes than the control or limed plot, thus two samples were taken at node number 10.

The leaves from the limed plots were generally similar in manganese concentrations to those from the untreated plots, although more samples were obtained from the longer vines. It is apparent that the manganese concentration increased with age of leaf up to node 16, with a slight decline indicated at node 18. All of the leaves from this plot appeared normal in color and healthy at sampling time as contrasted with those from the sulfur-treated plots which had almost a ten-fold increase in manganese concentration.

In the 1966 season, soil samples and foliar samples were taken from plots representing all combinations of soil amendment and fertilizer applications. In obtaining samples of the foliage, only the tenth leaf from the terminal bud was used to represent a hill, in view of results in the previous year. Other than that, the sampling technique was the same as that used in 1965. These samples were taken on August 3, 1966, and the results of the analyses appear in Table 10.

In the plots where no amendment had been applied, the soil pH had been depressed significantly by the use of fertilizer, although the value was still above 5.0. The sulfur-treated plots were very acid, with little difference in pH due to fertilizer application. On the other hand, in the limed soil the pH approached neutrality when no fertilizer was used, but the application of fertilizer depressed the pH value significantly.

The levels of extractable calcium followed a logical pattern in that they were intermediate in the control plots, relatively low in the sulfur-treated plots, and high in the limed plots. The use of fertilizer had little influence on the extractable calcium level in any plot.

Extractable soil manganese showed a behavior pattern similar to that of the previous year. That is, relatively low levels were extracted from the untreated soil and the limed soil while high levels were obtained from the acid (sulfur-treated) soil. However, the levels from the acid plots were not quite so high as they were in the previous year, 1965. Fertilizer use appeared to have no consistent effect on manganese extractability.

Table 10. — Soil reaction, extractable soil calcium and manganese, and manganese content of sweet potato leaves* taken from plots which had received different soil amendment and fertilizer treatments, 1966

Treatment	Soil ph	Extractable Ca - PPM**	Extractable Mn - PPM**	Leaf Mn Content - PPM***
No Amendment No Fertilizer	5.8	610	15	538
No Amendment 30-60-30/A	5.1	550	22	645
320# Sulfur/A No Fertilizer	4.4	357	79	2667
320# Sulfur/A 30-60-30/A	4.3	413	91	3097
1000# Lime/A No fertilizer	6.8	1070	21	408
1000# Lime/A 30-60-30/A	6.3	947	15	292
LSD (.05)	0.3	150	29	1145
LSD (.01)	0.5	213	41	1629

*Sampled on August 3, 1966 at the tenth node from the terminal bud.
**PPM of air-dry soil.
***PPM of oven-dry tissue.

Leaf manganese concentrations showed wide differences due to amendment applications. Apparently normal and healthy, leaves from the limed plots contained the lowest concentration of manganese, 292 to 408 ppm. In addition, healthy foliage from the untreated soil also had relatively low levels of manganese, 438 to 645 ppm. On the contrary, the chlorotic foliage from the sulfur-treated plots contained much higher concentrations of the element, 2667 to 3097 ppm.

During the following growing season, 1967, additional soil and foliar samples were taken from plots representing all combinations of soil amendment and fertilizer applications. These samples were obtained from the field on August 2, 1967, and were handled in the same manner as those taken in 1966. The analytical results obtained with these samples are shown in Table 11.

The effects of soil amendment and fertilizer on the soil reaction closely paralleled those of the previous year, namely, that the control plots were moderately acid, the sulfur-treated plots were highly acid, and the limed plots approached neutrality, with fertilizer use also exerting a depressing effect on soil pH.

Likewise, as in 1966, the major influence on extractable soil calcium was soil amendment application. More specifically, the untreated soil was intermediate, the sulfur-treated soil was lowest, and the limed soil was highest in extractable calcium content. Fertilizer use had little bearing on this constituent of the soil.

Also, as was true in the previous year, the primary factor affecting the extractability of soil manganese was the application of the sulfur amendment. This treatment greatly increased the level of extractable manganese,

Table 11. — Soil reaction, extractable soil calcium and manganese, and manganese content of sweet potato leaves* taken from plots which had received different soil amendment and fertilizer treatments, 1967

Treatment	Soil pH	Extractable Ca - PPM**	Extractable Mn - PPM**	Leaf Mn Content - PPM***
No Amendment No Fertilizer	5.4	340	24	458
No Amendment 30-60-30/A	5.1	433	24	494
320# Sulfur/A No Fertilizer	4.4	195	56	1598
320# Sulfur/A 30-60-30/A	4.3	190	87	2823
1000# Lime/A No Fertilizer	6.9	765	28	320
1000# Lime/A 30-60-30/A	6.3	740	22	297
LSD (.05)	0.4	102	20	846
LSD (.01)	0.5	139	27	1154

*Sampled on August 2, 1967 at the tenth node from the terminal bud.
**PPM of air-dry soil.
***PPM of oven-dry tissue

while the control plots and the limed soil remained at relatively low levels.

As for leaf manganese in 1967, the chlorotic foliage from the sulfur-treated soil was by far the highest in manganese concentration. Ranking second were the control plots, with foliage from the limed plots falling slightly below the foliage from the untreated soil. No consistent influence of fertilizer use was shown on foliar manganese concentration. The leaves from the control plots and the limed plots appeared perfectly healthy and normal.

In 1968, more elaborate plans were formulated to allow a more thorough investigation into the actual cause of the development of the symptoms of abnormal foliage. Preparations were made and preliminary chemical analyses were conducted on soil samples and foliar samples in accordance with procedures outlined under Materials and Methods.

During the seasons of 1969 and 1970, soil samples were taken from each plot in March, June, and August. The samples in June were taken from each plot at the same time as a foliar sample was taken. The soil was tested in the laboratory for reaction and for extractable calcium, manganese, iron, and aluminum. The results of these analyses appear in Table 12.

The soil reaction in the plots receiving no amendment remained fairly constant at the moderately acid level throughout the sampling period in both seasons. The use of fertilizer appeared to have a slightly depressing effect on the soil pH. The sulfur-treated plots continued to show strong acidity, with some tendency to become more acid with the passage of the season. On the other hand, the limed plots remained near neutrality in reaction during the sampling period of both seasons, with only a slight trend toward acidification as a result of fertilization.

In the control (not amended) plots in 1969, calcium was extractable at

Table 12. — The effect of soil amendments and fertilizer applications on the soil reaction and the level of extractable calcium, manganese, iron, and aluminum in the topsoil of Grenada silt loam sampled on three dates during the growing seasons of 1969 and 1970

Treatment	Growing Season	Time of Sampling														
		March					June					August				
		Soil pH	Ca*	Mn*	Fe*	Al*	Soil pH	Ca*	Mn*	Fe*	Al*	Soil pH	Ca*	Mn*	Fe*	Al*
No Amendment No Fertilizer	1969	5.7	618	71	1.2	52	5.5	577	83	1.2	57	5.6	588	82	1.2	47
	1970	5.8	336	71	1.2	51	5.5	328	70	1.3	55	5.4	393	48	1.2	49
No Amendment 30-60-30/A	1969	5.6	736	74	1.2	59	5.1	802	151	1.3	56	5.2	704	101	1.5	52
	1970	5.6	378	74	1.2	56	5.0	411	132	1.4	60	5.3	450	58	1.4	53
320# Sulfur/A No Fertilizer	1969	4.6	300	116	5.5	114	4.4	334	161	6.6	119	4.4	230	158	6.8	118
	1970	4.7	143	127	5.6	117	4.2	135	179	9.1	140	4.3	151	151	8.4	130
320# Sulfur/A 30-60-30/A	1969	4.4	333	119	6.8	112	4.1	529	188	7.4	120	4.1	372	170	9.2	125
	1970	4.5	147	121	7.4	122	4.0	124	211	10.8	162	4.1	138	170	10.4	131
1000# Lime/A No Fertilizer	1969	7.1	1264	37	0.6	30	7.0	1318	36	0.6	33	7.2	1344	37	0.6	26
	1970	7.1	767	36	0.6	27	7.0	909	33	0.7	32	7.2	1004	28	0.6	25
1000# Lime/A 30-60-30/A	1969	7.0	1261	39	0.6	29	6.3	1398	70	0.6	34	6.8	1308	41	0.6	28
	1970	6.9	740	42	0.7	27	6.7	925	43	0.6	31	7.0	943	27	0.6	26
LSD .05	1969	0.4	102	14	1.9	17	0.3	85	25	3.3	22	0.4	116	18	5.3	20
	1970	0.4	94	13	2.1	22	0.3	103	19	2.4	21	0.3	103	26	2.6	22
LSD .01	1969	0.5	139	20	2.6	23	0.5	115	35	4.5	31	0.5	158	24	7.2	28
	1970	0.5	129	18	2.9	30	0.4	141	26	3.2	29	0.4	141	36	3.4	31

*PPM of the element extractable with 1 N ammonium acetate solution buffered at pH 4.8.

fairly constant levels during the season, at levels which might be expected in this soil at the prevailing pH; however, during the 1970 season the calcium levels were greatly reduced and were measured at about half of that for the 1969 season. The use of fertilizer tended to increase the amount of extractable calcium in the soil in the control plots. The sulfur-treated plots showed greatly reduced levels of extractable calcium on all sampling dates. Again, far less calcium was extracted from these plots in 1970 than in 1969. The limed plots contained several times more extractable calcium than the sulfur-treated plots and roughly twice as much as the control plots. The indication was strong here also that more calcium was extractable in 1969 than in 1970. By way of explanation, one cannot discount the possibility of some variation from one season to another in the degree of precision in the analytical laboratory, whether the variation be in human efficiency or reagent chemical purity or standardization of equipment.

Extractable soil manganese in all samples was markedly affected by soil amendment treatment. Although some variation was shown by samples from the control plots, the major effect on the element was caused by the applications of sulfur. It is clearly shown that the use of this amendment caused marked increases in manganese extractability throughout the season. Conversely, the use of lime reduced the amount of manganese extracted from the soil.

The amount of iron extractable from the soil was also increased several fold by the application of sulfur to the soil. Liming the soil had the opposite effect, in that it reduced extractable iron by about half its original amount.

The extractability of aluminum from the soil was likewise profoundly affected by soil amendment use. Acidifying the soil with sulfur applications markedly increased the levels of extractable aluminum while making the soil more alkaline by the use of lime had the opposite effect.

The relationships between the soil reaction and the levels of extractable calcium, manganese, iron, and aluminum expressed in terms of simple correlation coefficients are presented in Table 13. It is shown that the soil pH and calcium levels were closely related in a positive manner. On the other hand, extractable soil manganese was definitely related to soil reaction in a negative way, as were soil iron and aluminum. The simplest inference from this table is that as the soil became more acid, less calcium but more manganese, iron, and aluminum were extractable from it. The probability of this inference is high, in view of the large r values.

During the growing seasons of 1969 and 1970, samples of the leaves were taken in June from each plot. Representative samples were obtained from both the sixth nodal position from the terminal bud and the tenth nodal position. The samples were classified with respect to severity of symptoms (chlorosis primarily) and then were analyzed in the laboratory for calcium, manganese, iron, and aluminum contents. The resulting information, along with the pH data on soil samples taken from these plots at the same time, are presented in Table 14.

Table 13. — The relationship between the soil reaction and the levels of extractable* calcium, manganese, iron, and aluminum determined in March, June, and August of 1969 and 1970

Sampling Date	Soil Variables	r Value 1969	r Value 1970	r Value Both Years
March	Soil pH with Extractable Soil Calcium	0.96	0.97	0.95
	Soil pH with Extractable Soil Manganese	-0.94	-0.91	-0.92
	Soil pH with Extractable Soil Iron	-0.79	-0.80	-0.80
	Soil pH with Extractable Soil Aluminum	-0.89	-0.92	-0.90
June	Soil pH with Extractable Soil Calcium	0.87	0.96	0.94
	Soil pH with Extractable Soil Manganese	-0.88	-0.94	-0.91
	Soil pH with Extractable Soil Iron	-0.78	-0.79	-0.76
	Soil pH with Extractable Soil Aluminum	-0.86	-0.87	-0.87
August	Soil pH with Extractable Soil Calcium	0.94	0.97	0.96
	Soil pH with Extractable Soil Manganese	-0.94	-0.86	-0.92
	Soil pH with Extractable Soil Iron	-0.76	-0.79	-0.77
	Soil pH with Extractable Soil Aluminum	-0.87	-0.89	-0.92
r value required for significance at .05 level		0.32	0.32	0.23
r value required for significance at .01 level		0.42	0.42	0.30

*Extracted with 1 N ammonium acetate buffered at pH 4.8.

In the younger (sixth) leaves, the calcium level varied widely with season. Among treatment samples, calcium accumulation was depressed by the sulfur amendment and promoted by lime use. The application of fertilizer reduced the concentration of calcium in the leaves from all plots. The manganese concentration in the leaves from the control (unamended) plots varied somewhat, both with season and with fertilizer application. It may be noted that the highest manganese concentration in the control samples, 2023 ppm, was associated with a soil pH of 5.1 and a chlorosis severity rating of 2.00, while the lowest concentration of manganese, 218 ppm, was related to a soil pH of 5.5 and a chlorosis value of 1.47. The samples from the sulfur-treated soil were much higher in manganese, with some variation indicated due to fertilization. The range of manganese in these samples was 4353 to 6206 ppm, with a soil pH range of 4.0 to 4.4. These leaves were very chlorotic before analysis, as shown by the high severity values ranging from 3.00 to 5.30. The leaves from the limed soil were relatively low in manganese concentration (201 to 694 ppm), the value apparently related to soil pH and fertilizer application. Before analysis, these leaves were completely free of the chlorosis that was so pronounced on the samples from the sulfur-treated soil and also somewhat noticeable on the control samples. The iron concentration of the foliage appeared to be largely unaffected by soil amendment or fertilizer application; however, the leaves did show a tendency to accumulate more iron

Table 14. — The effect of soil amendments and fertilizer applications on the soil reaction and the concentrations of calcium, manganese, iron, and aluminum in sweet potato leaves and on the severity of symptoms appearing on the leaves sampled in June of 1969 and 1970

Treatment	Growing Season	Soil pH	Area Sampled									
			Sixth Leaf from Terminal Bud					Tenth Leaf from Terminal Bud				
			Ca*	Mn*	Fe*	Al*	Severity**	Ca*	Mn*	Fe*	Al*	Severity**
No Amendment	1969	5.5	8516	421	151	528	1.40	--	--	--	--	--
No Fertilizer	1970	5.5	3933	218	122	432	1.47	11367	548	185	768	1.02
No Amendment	1969	5.1	7200	2023	115	384	2.00	17083	4105	179	505	3.40
30-60-30/A	1970	5.0	795	735	87	371	1.09	12833	2850	115	440	1.78
320# Sulfur/A	1969	4.4	4656	4353	143	650	3.80	--	--	--	--	--
No Fertilizer	1970	4.2	1260	4358	62	881	3.00	7160	5900	233	1216	3.84
320# Sulfur/A	1969	4.1	3912	6206	165	817	5.30	7858	8470	229	1204	5.30
30-60-30/A	1970	4.0	1238	5194	139	997	4.52	7433	6383	255	1358	5.17
1000# Lime/A	1969	7.0	11333	294	209	824	1.00	--	--	--	--	--
No Fertilizer	1970	7.0	8508	201	186	646	1.00	15400	342	245	1030	1.00
1000# Lime/A	1969	6.3	7983	694	121	422	1.00	22183	1149	142	463	1.00
30-60-30/A	1970	6.7	2298	262	96	336	1.00	13100	731	110	360	1.00
LSD (.05)	1969	0.3	1240	1162	33	184	1.10	5853	1060	60	147	0.96
	1970	0.3	3185	1316	60	313	0.75	2718	1241	78	420	0.80
LSD (.01)	1969	0.5	1692	1582	45	251	1.15	8225	1508	86	209	1.36
	1970	0.4	4344	1795	82	438	1.22	3707	1692	107	573	1.15

*PPM of the element on a dry weight basis.
**Based on a scale of 1 for no symptoms to 9 for very severe symptoms.

from all plots in 1969 than in 1970. The aluminum concentration did not appear in a regular pattern among treatment effects. That is, while acidification of the soil by sulfur applications increased the aluminum in the leaves, a similar response was noted from neutralizing the soil acidity with lime in the plots where no fertilizer was applied. Furthermore, the effect of fertilizer use on foliar aluminum was inconsistent, sometimes increasing it and at other times decreasing it. An interesting point is that some of the leaves that were among the highest in aluminum concentration showed no sign of chlorosis whatsoever.

In the older (tenth) leaves, the calcium level was considerably higher in all samples than it was in the younger ones (sixth), as shown in Table 14. In 1969, the unfertilized plots had not produced ten nodes of growth by June, so no data was obtained for them. In the control (unamended) plot, the use of fertilizer did not appear to affect the concentration of calcium in the foliage. The outstanding effect of the amendments was the repression of foliar calcium in the samples from the sulfur-treated soil. Conversely, foliar calcium concentrations were highest in the leaves from the limed plots, with only relatively small influences of fertilizer use being shown. As for foliar manganese, the control plot samples which varied in severity of symptoms from slight to moderate contained widely different amounts of manganese (548 ppm from plots with a pH of 5.5 to 4105 ppm from plots with a pH of 5.1). However, by far the highest concentration of foliar manganese (5900 to 8470 ppm) was found in the samples from the sulfur-treated soil (pH 4.0 to 4.4). These leaves were very chlorotic before analysis, ranging in severity from 3.84 to 5.30. Leaves collected from the limed plots were much lower in manganese (342 to 1149 ppm) and showed no chlorotic symptoms whatsoever. As for foliar iron concentration, the differences, although sometimes significant, did not follow any regular pattern of influence by soil amendment or fertilizer application. The aluminum concentration of the leaves varied inconsistently with soil amendment application and pH. The samples highest in aluminum (1358 ppm) were obtained from the sulfur-treated plots (pH 4.0); however, the samples which were intermediate in aluminum (1030 ppm) came from the limed soil (pH 7.0). These leaves were entirely free of chlorotic symptoms while some of those from the control (unamended) plot which contained only 505 ppm of aluminum were moderately chlorotic.

Some of the relationships indicated by the data in Table 14 between the severity of the chlorotic symptoms on the foliage, the soil pH, the levels of extractable calcium, manganese, iron, and aluminum from the soil, and the concentrations of these elements in the leaves are better understood when expressed in terms of correlation coefficients as in Table 15. It is clear from the consistently high negative r value that the chlorosis in the foliage became more severe as the soil pH was reduced. This negative association was also shown between the extractable soil calcium and the degree of

Table 15. — The relationship between the severity of symptoms on the sixth and tenth leaves* from the terminal bud and the soil* pH, the levels of extractable calcium, manganese, iron, and aluminum from the soil, and the concentrations of these elements in the leaves in 1969 and 1970

Variables	r Value			
	Sixth Leaf		Tenth Leaf	
	1969	1970	1969	1970
Severity with Soil pH	-0.79	-0.74	-0.79	-0.79
Severity with Extractable Soil Calcium	-0.74	-0.77	-0.44	-0.70
Severity with Extractable Soil Manganese	0.79	0.82	0.44	0.87
Severity with Extractable Soil Iron	0.86	0.94	0.36	0.88
Severity with Extractable Soil Aluminum	0.83	0.87	0.12	0.88
Severity with Leaf Calcium	-0.75	-0.27	-0.35	-0.75
Severity with Leaf Manganese	0.94	0.98	0.66	0.87
Severity with Leaf Iron	0.07	0.29	0.36	0.33
Severity with Leaf Aluminum	0.46	0.73	0.39	0.49
r value required for significance at .05 level	0.32	0.32	0.46	0.32
r value required for significance at .01 level	0.42	0.42	0.59	0.42

*Sampled in June, 1969 and 1970.

chlorosis of the foliage. Equally definite was the positive association between extractable soil manganese and severity of chlorosis, illustrating that the soil that released the most manganese to the extractant also produced sweet potato foliage that was the most chlorotic. The severity of chlorosis was also positively related to extractable soil iron and aluminum. In regard to foliar levels of these elements, leaf calcium was negatively related to severity of chlorosis; however, leaf manganese was consistently positively associated with chlorosis, meaning that the higher the concentration of leaf manganese the greater the degree of chlorosis of the foliage. Leaf iron showed some tendency toward positive relation with severity of symptoms, but the r value was much lower than that for leaf manganese. This was also true for leaf aluminum.

Other relationships such as that between the soil reaction and the concentrations of calcium, manganese, iron, and aluminum in the leaves, as well as that between the levels of extractable soil calcium, manganese, iron, and aluminum, and the concentrations of these elements in the leaves are presented as correlation values in Table 16.

It is clear from the r values presented that the soil pH was positively related to the calcium concentration of the leaves; however, the opposite was true with respect to leaf manganese and soil pH, a good indication that as the soil became more acid more manganese was accumulated in the leaves. The soil reaction did not have a consistent influence on the iron concentration in the leaves, and the aluminum concentration in the foliage, although negatively related to soil pH, did not show as close an association with it as did foliar manganese. The r values indicate that extractability of both calcium and manganese from the soil is a good index of what the concentration of these elements may be in the foliage. These indications are also shown for soil iron with leaf iron and soil aluminum with leaf

Table 16. — The relationship between the soil* pH and the concentrations of calcium, manganese, iron, and aluminum in the sixth and tenth leaves* from the terminal bud, and the relationship between the extractable levels of these elements in the soil and their concentrations in the leaves in 1969 and 1970

Variables	r Values			
	Sixth Leaf		Tenth Leaf	
	1969	1970	1969	1970
Soil pH with Leaf Calcium	0.88	0.56	0.74	0.79
Soil pH with Leaf Manganese	-0.82	-0.77	-0.91	-0.81
Soil pH with Leaf Iron	0.26	0.03	-0.68	-0.19
Soil pH with Leaf Aluminum	-0.06	-0.46	-0.81	-0.37
Extractable Soil Calcium with Leaf Calcium	0.69	0.45	0.81	0.77
Extractable Soil Manganese with Leaf Manganese	0.83	0.85	0.87	0.83
Extractable Soil Iron with Leaf Iron	0.15	0.32	0.65	0.43
Extractable Soil Aluminum with Leaf Aluminum	0.43	0.70	0.43	0.58
r value required for significance at .05 level	0.32	0.32	0.46	0.32
r value required for significance at .01 level	0.42	0.42	0.59	0.42

*Sampled in June, 1969 and 1970.

aluminum, but the probability values substantiating these relationships are much lower than those for calcium and manganese, meaning that extractability of iron and aluminum from the soil is not as good an index of accumulation of these elements by the foliage as is that for calcium and manganese.

During the seasons of 1969 and 1970, additional foliar samples were taken from each treatment plot in August. Representative samples were obtained from each of the sixth, tenth, and fourteenth nodal positions. Each sample was rated for severity of chlorosis and then analyzed for calcium, manganese, iron, and aluminum contents. The information gained, along with soil pH data on samples taken at the same time, is shown in Table 17.

The youngest leaves (sixth node) showed wide variation in calcium level between seasons in all plots. Among treatment samples, the concentration of calcium was reduced by sulfur applications and unaffected by lime use. This lack of response to lime application does not coincide with the results obtained with the samples taken in June. The use of fertilizer tended to reduce the calcium level in all samples. The manganese level in these leaves was also affected by season as well as amendment. In all cases, manganese was higher in 1969. The greatest response in foliar manganese was to sulfur applications where the levels were sharply increased; however, the levels in these samples were much lower than that in the corresponding samples taken in June (Table 14). It is noteworthy also that these samples, even with as much as 1292 ppm of manganese, showed no signs of chlorosis. The use of lime tended to reduce manganese in the foliage. Neither soil amendment nor fertilizer application appeared to have any influence on the iron level in the leaves, and the aluminum concentration showed only small irregular variations with treatment. Again, it should be noted that none of these leaves displayed any signs of chlorosis.

Table 17. — The effect of soil amendments and fertilizer applications on the soil reaction and the concentration of calcium, manganese, iron, and aluminum in sweet potato leaves and on the severity of symptoms appearing on leaves sampled in August of 1969 and 1970

Treatment	Growing Season	Soil pH	Area Sampled														
			Sixth Leaf from Terminal Bud					Tenth Leaf from Terminal Bud					Fourteenth Leaf from Terminal Bud				
			Ca*	Mn*	Fe*	Al*	Severity**	Ca*	Mn*	Fe*	Al*	Severity**	Ca*	Mn*	Fe*	Al*	Severity**
No Amendment	1969	5.6	1552	273	128	369	1.00	4182	431	150	461	1.00	6683	556	218	704	1.00
No Fertilizer	1970	5.4	282	75	129	423	1.00	1217	296	125	501	1.02	3817	492	165	624	1.01
No Amendment	1969	5.2	1282	268	78	253	1.00	3322	470	102	320	1.02	8150	780	144	489	1.00
30-60-30/A	1970	5.3	310	92	74	293	1.00	1150	340	65	276	1.07	2317	545	95	355	1.00
320# Sulfur/A	1969	4.4	919	881	87	301	1.00	2218	1589	176	563	1.02	4223	2418	237	775	1.09
No Fertilizer	1970	4.3	325	511	123	438	1.00	933	1564	137	571	1.09	1958	2430	188	713	1.02
320# Sulfur/A	1969	4.1	810	1292	78	348	1.00	2128	2871	121	339	1.15	5007	3917	178	522	1.27
30-60-30/A	1970	4.1	392	710	91	353	1.00	1008	2135	115	424	1.27	2483	3498	137	494	1.68
1000# Lime/A	1969	7.2	1567	167	79	251	1.00	7417	278	94	295	1.00	14950	379	162	487	1.00
No Fertilizer	1970	7.2	403	68	97	348	1.00	2117	209	111	413	1.00	7117	297	134	514	1.00
1000# Lime/A	1969	6.8	1102	167	81	231	1.00	5058	249	83	252	1.00	11150	381	112	336	1.00
30-60-30/A	1970	7.0	322	41	65	253	1.00	1392	201	66	243	1.00	5042	286	82	277	1.00
LSD (.05)	1969	0.4	471	349	31	113	NS	2101	752	37	124	NS	2182	1075	42	154	NS
	1970	0.3	NS	295	36	NS	NS	353	842	38	148	NS	1654	1123	46	154	NS
LSD (.01)	1969	0.5	643	476	42	154	--	2898	1025	51	169	--	2976	1466	58	210	--
	1970	0.4	NS	403	49	NS	--	481	1148	52	201	--	2256	1532	63	210	--

*PPM of the element on a dry weight basis.

**Based on a scale of 1 for no symptoms to 9 for very severe symptoms.

The medium-age leaves (tenth node) were much higher in calcium than the younger ones (sixth node), with the concentrations in all samples in 1969 considerably above those in 1970 (Table 17). Again, the depressing effect of sulfur applications to the soil on foliar calcium levels was shown, as was the stimulating influence of lime applications. Fertilization was inconsistent in its effect on foliar calcium. The manganese levels were lower in the younger leaves. Some of the leaves in the control plots were showing traces of chlorosis, although the manganese concentrations were well below those which had previously been associated with foliar chlorosis. Again, the soil which had been acidified by use of sulfur produced leaves much higher in manganese concentration than the other leaves. Fertilization also appeared to increase foliar manganese levels. The leaves from the sulfur-treated plots, with 1564 to 2871 ppm of manganese, were showing a mild degree of chlorosis while those from the limed soil were not showing any discoloration. The samples from the limed plots, at 201 to 278 ppm, were also far below those from the highly acid soil in manganese concentration. The accumulation of iron by the leaves appeared to be independent of soil or fertilizer use. Similarly, no clear-cut pattern of aluminum accumulation was shown, although some of the samples from the highly acid soil appeared to be higher in aluminum than others.

The oldest leaves (fourteenth node) were even higher in calcium concentration than the middle-aged ones (Table 17). The effect of season was still present in that leaves in 1969 accumulated more calcium than those in 1970. The depressing effect of sulfur applications and the stimulating influence of lime use on foliar calcium were still evident in leaves of this age. A fertilization influence on foliar calcium accumulation was inconsistent. The manganese levels were generally higher in these leaves than they were in the middle-aged or youngest leaves. Practically no chlorotic symptoms could be found on the leaves from the control (unamended) plots which varied in manganese concentration from 492 to 780 ppm. However, the leaves from the sulfur-treated soil (pH 4.1 to 4.4) contained from 2418 to 3917 ppm of manganese and were showing mild symptoms of chlorosis in most cases. The limed soil (pH 6.8 to 7.2) produced leaves with 297 to 318 ppm of manganese and had no sign of chlorosis. The foliar iron concentration again showed no response to either soil amendment or fertilizer application. The pattern for foliar aluminum was so varied that it was difficult to assign a definite response to either soil amendment or fertilizer application.

Some of the relationships shown in tabular form in Table 17 between treatment factors and effects are summarized in Table 18 in correlation form as r values. With one exception, sixth leaf-1970, the results point to a fairly close relationship between soil pH and leaf calcium level. This inference is in agreement with the results obtained with the samples taken

Table 18. — The relationship between the soil* pH and the concentrations of calcium, manganese, iron, and aluminum in the sixth, tenth, and fourteenth leaves* from the terminal bud, and the relationship between the extractable levels of these elements in the soil and their concentrations in the leaves in 1969 and 1970

Variables	r Value					
	Sixth Leaf		Tenth Leaf		Fourteenth Leaf	
	1969	1970	1969	1970	1969	1970
Soil pH with Leaf Calcium	0.46	0.03	0.77	0.72	0.88	0.64
Soil pH with Leaf Manganese	-0.71	-0.65	-0.71	-0.64	-0.74	-0.73
Soil pH with Leaf Iron	-0.04	-0.29	-0.50	-0.36	-0.46	-0.39
Soil pH with Leaf Aluminum	-0.29	-0.26	-0.45	-0.38	-0.47	-0.38
Extractable Soil Calcium with Leaf Calcium	0.34	0.09	0.74	0.74	0.90	0.68
Extractable Soil Manganese with Leaf Manganese	0.73	0.81	0.77	0.76	0.80	0.89
Extractable Soil Iron with Leaf Iron	-0.11	0.28	0.39	0.46	0.39	0.45
Extractable Soil Aluminum with Leaf Aluminum	0.31	0.38	0.54	0.51	0.54	0.50
r value required for significance at .05 level	0.32	0.32	0.32	0.32	0.32	0.32
r value required for significance at .01 level	0.42	0.42	0.42	0.42	0.42	0.42

*Sampled in August,1969 and 1970.

in June. Furthermore, as was true with the June sample, a highly negative association was shown between soil pH and foliar manganese level, meaning that the more acid soil resulted in increased accumulation of manganese by the leaves. Again, as in June, neither leaf iron nor leaf aluminum showed a very high dependence on soil pH, although the r value was consistently negative. The extractability of calcium, and especially manganese, from the soil had a major influence on the concentration of these elements in the leaves. This relationship was also found with the samples taken in June. The amount of extractable iron in the soil showed some relationship to foliar iron, and aluminum extractability was generally related to foliar aluminum concentration.

The disease data shown in Tables 19 and 20 show highly significant effects due to amendments and thereby confirm the effectiveness of sulfur application to the soil for controlling soil rot and the importance of soil pH in determining soil rot severity as previously reported (*26, 34, 35*). These data also show highly significant differences in disease severity from year to year with the lowest severity index of 18.5 in 1967 and the highest of 29.8 in 1966. Such variability in soil rot severity during different growing seasons was reported earlier (*34*). There was a significant interaction indicated between amendment and fertilizer with soil rot severity greater in the limed plots receiving no fertilizer than in those fertilized, while soil rot severity was lower in the unfertilized than in the fertilized plots receiving sulfur or no amendment. There also was a significant interaction indicated between years and amendments. This appears to be due to the increase of soil rot severity in the sulfur-treated plots and the decrease in severity index in the limed plots in 1973, two years after addition of amendments ceased, as well as to the gradual increase in severity in plots receiving no amendments.

The results in Table 21 show the effects of the treatments on vine growth.

Table 19. — Percentage[1] soil-rot-affected Centennial sweet potatoes grown on Grenada silt loam soil with different soil amendments and fertilizer applications at Chase, La., 1965-70 and 1973

	Years and Percentages							
Amendment-Fertilizer	1965	1966	1967	1968	1969	1970	1973	Average
none - none	20.3	29.7	30.0	36.3	47.7	42.3	43.2	35.6
none - 30-60-30/A	23.3	12.2	35.0	53.5	48.3	52.2	53.8	39.8
320# S/A - none	5.8	6.2	11.0	4.5	13.8	9.5	17.7	9.8
320# S/A - 30-60-30/A	6.0	3.0	10.5	4.3	24.8	13.3	22.7	12.1
1000# Lime/A - none	72.7	90.3	82.7	91.3	90.0	76.2	70.8	82.0
1000# Lime/A - 30-60-30/A	63.0	60.8	77.2	86.7	77.5	86.7	62.3	73.5
Average	31.9	33.7	41.1	46.1	50.4	46.7	45.1	42.1

1/ Averages of 6 replications.

A summary of the statistical analysis of the combined data for the seven years is given. Amendments and fertilizer were considered fixed effects and years as random effects in the analysis. Mean square for Error D was 361.9. * and ** denote significance at the 5% and 1% level of probability, respectively.

Analysis Summary:

Source of Variation	Degrees of Freedom	Error Term Used	F-values
Total	251		
Columns/years	35	D	0.57
Rows/years	35	D	1.21
Years	6	D	4.82**
Amendments	2	A	130.68**
Fertilizer	1	B	0.06
Amend. x Fert.	2	C	6.58*
Years x Amend. (Error A)	12	D	2.01*
Years x Fert. (Error B)	6	D	1.53
Years x Amend. x Fert. (Error C)	12	D	0.41
Remainder (Error D)	140		

Table 20. — Soil rot severity indexes[1] on Centennial sweet potatoes grown on Grenada silt loam soil with different soil amendments and fertilizer applications at Chase, La., 1965-70 and 1973

Amendment-Fertilizer	1965	1966	1967	1968	1969	1970	1973	Average
	Years and Percentages							
none - none	10.2	15.2	11.2	20.0	21.5	19.0	23.0	17.1
none - 30-60-30/A	13.3	6.0	13.0	28.2	19.8	24.8	33.0	19.7
320# S/A - none	2.0	2.7	3.7	2.2	4.3	3.0	9.3	3.9
320# S/A - 30-60-30/A	2.0	1.3	3.5	1.5	7.2	4.0	11.7	4.5
1000# Lime/A - none	57.3	55.7	43.8	65.5	51.2	38.5	42.2	50.6
1000# Lime/A - 30-60-30/A	41.8	32.3	36.0	61.2	35.8	50.8	40.7	42.7
Average	21.1	18.9	18.5	29.8	23.3	23.4	26.6	23.1

1/ Averages of 6 replications.

A summary of the statistical analysis of the combined data for the 7 years is given. Amendments and fertilizer were considered fixed effects and years as random effects in the analysis. Mean square for error D was 197.88. * and ** denote significance at the 5% and 1% levels of probability, respectively.

Analysis Summary:

Source of Variation	Degrees of Freedom	Error Term Used	F-values
Total	251		
Columns/years	35	D	0.47
Rows/years	35	D	0.73
Years	6	D	3.02**
Amendments	2	A	91.89**
Fertilizer	1	B	0.51
Amend. x Fert.	2	C	5.70*
Years x Amend. (Error A)	12	D	2.16*
Years x Fert. (Error B)	6	D	1.58
Years x Amend. x Fert. (Error C)	12	D	0.58
Remainder (Error D)	140		

The soil rot fungus causes rotting of the small feeder roots resulting in stunting of the plants (*34, 35*). Therefore, severity of soil rot is indicated by vigor and amount of vine growth. The data in Table 21 show highly significant effects due to years as expected because of the soil moisture relationships to soil rot (*34, 35*). There also was a significant effect on vine growth due to fertilizer with the best vine growth generally shown in the fertilized plots. There was a highly significant interaction indicated between years and amendment, which was related more to injury caused by low pH in the sulfur plots in 1970 than to disease, although there was evidence of greater disease severity in 1970 in the plots receiving no amendment, resulting in considerably poorer vine growth in those plots. There was also a highly significant interaction indicated between years, amendments, and fertilizers (Table 21).

There was a highly significant positive correlation for the 7 years' data between average disease severity indexes in each of the six treatments and average soil pH values in each of the six treatment plots. The correlation coefficient for this comparison was 0.935.

The results from the disease data obtained in this experiment confirm the effectiveness of sulfur application to the soil in controlling soil rot, but emphasize the pitfalls of using this practice unless very carefully controlled applications are made based on adequate soil tests over the entire field under consideration. The data also show that adding lime to soils with pH of 5.2 will greatly enhance soil rot development when the causal fungus is present.

Table 21. — Vine growth ratings[1] on Centennial sweet potatoes grown on Grenada silt loam soil with different soil amendments and fertilizer applications at Chase, La., 1965, 1966, and 1970

Amendment-Fertilizer	Year and Vine Growth Rating 1965	1966	1970	Average
none - none	3.0	3.5	1.8	2.77
none - 30-60-30/A	4.0	3.8	4.0	3.93
320# S/A - none	2.8	3.2	2.3	2.77
320# S/A - 30-60-30/A	3.2	3.5	2.2	2.97
1000# Lime/A - none	2.0	1.3	1.5	1.60
1000# Lime/A - 30-60-30/A	3.3	3.3	3.3	3.30
Average	3.08	3.10	2.52	2.90

1/ Averages of 6 replications. Each plot was rated into one of 4 classes: 1 = poor; 2 = fair; 3 = good; 4 = very good vine growth 7 to 9 weeks after planting.

A summary of the statistical analysis of the combined data for the 3 years is given. Amendments and fertilizer were considered as fixed effects and years as random effects in the analysis. Mean square for error D was 0.2585. * and ** denote significance at the 5% and 1% levels of probability, respectively.

Analysis Summary:

Source of Variation	Degrees of Freedom	Error Term Used	F-values
Total	107		
Columns/years	15	D	1.61
Rows/years	15	D	1.27
Years	2	D	14.43**
Amendments	2	A	6.53
Fertilizer	1	B	83.56**
Amendments x fertilizer	2	C	5.51
Years x amendment (Error A)	4	D	4.24**
Years x fertilizer (Error B)	2	D	1.39
Years x Amend. x Fert. (Error C)	4	D	4.06**
Remainder (Error D)	60		

Summary

The effect of changing the natural reaction of a Mississippi River Terrace soil (Grenada silt loam) on sweet potato growth, production, and quality was studied. The pH changes were interacted with fertilizer effects and were brought about by annual applications of sulfur and lime prior to fertilization.

As the sulfur-treated plots became more acid, plant growth was somewhat restricted, especially during the early part of the growing season. A definite pattern of chlorosis appeared on the foliage which was closely related to an abnormally high accumulation of manganese in the leaves. Other elements, such as aluminum and calcium, appeared to be less involved in causing the abnormality of the foliage. The amounts of manganese which could be easily extracted from the soil also increased markedly with decreases in the soil pH. Yields were decreased somewhat in the acidified soil.

As the limed plots became more alkaline, vine growth was reduced to some extent, especially in the unfertilized plots. Also, the yield of marketable potatoes was greatly reduced due to the incidence and severity of soil rot infection in the roots which was increased in proportion to the increase in soil pH. This type of response was also found in the potatoes from the sulfur-treated plots where soil rot infection was greatly reduced by the highly-acid soil.

Only minor differences were found in the dry matter or carotene content of the roots as a result of having been grown in the sulfur-treated or limed soil. Likewise, canning quality was not materially affected by soil amendment or fertilizer application.

The information presented herein illustrates the danger of growing sweet potatoes on Mississippi River Terrace soils that have become highly acid in reaction. This practice would probably result in the plants accumulating an excessive amount of manganese in the tissue, and depressed vine growth and corresponding reductions in yield may be noted.

Additional information presented in this bulletin points out the hazard of growing soil rot susceptible sweet potatoes on these soils that have been limed, providing conditions suitable for the development of the soil rot organism. In this case, the yield of marketable roots will probably be greatly reduced.

Therefore, because of the two undesirable prospects facing him in terms of improper soil reaction, the grower of soil rot susceptible sweet potatoes should maintain his soil pH in the moderately acid range for good production of high quality roots.

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